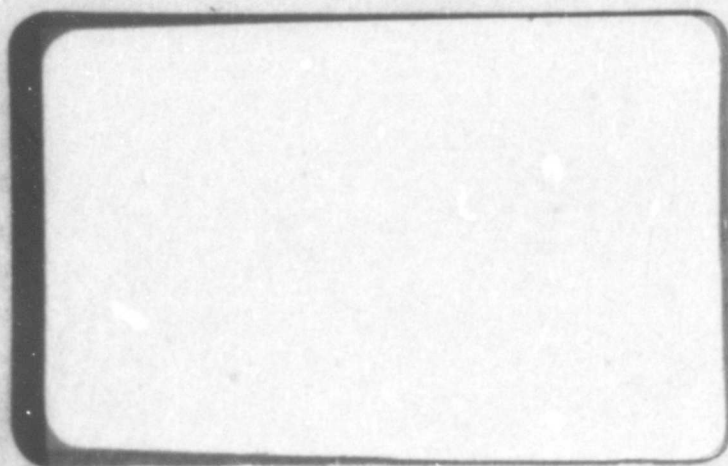
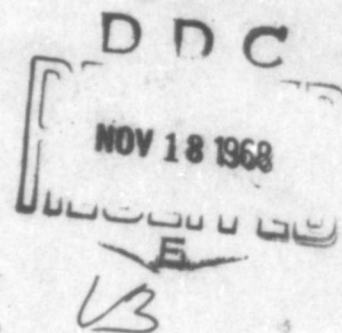


AD 672447



Distribution of this document
is unlimited.



Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va 22151

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

GENERAL DYNAMICS/CONVAIR

DEPARTMENT 190-2 FINAL REPORT

DYNAPAK FORGING

P.R. 904

W.O. 27094

Distribution of this document
is unlimited.

Prepared by

J. F. Murphy

J. F. Murphy
Mfg. Development Engineer, Sr.

Approved

W. E. Wise

W. E. Wise
Chief
Applied Mfg. Research

and

Carl F. Stark

C. F. Stark
Mfg. Development Engineer

Distribution 1.0k

GENERAL DYNAMICS
ASTRONAUTICS

OCT 24 1961

LIBRARY

ABSTRACT

Tooling concepts for forging and extrusion processes were developed. The developed tooling has demonstrated production practicality in the manufacture of test parts.

Detail test parts have shown grain size reduction in the forging process. The parts also demonstrated that precision forging and extrusion by the high energy rate process can be achieved in fewer stages than conventional processes.

Machine operating and safety procedures for the San Diego Dynapak unit were also established.

SUMMARY

Tooling concepts for forging and extrusion processes were developed. Two basic types of universal holders for both processes were evolved. One holder was pre-stressed and the other unstressed. The pre-stressed design was found to be more adaptable to extruding and the unstressed holder to the forging process. Sound, strong tooling developed for production capabilities has demonstrated operating practicability in the manufacture of test parts.

Detail parts made through the use of test tooling have shown grain size reduction in the forging process. An anticipated gain in strength due to the refinement of grain did not occur, however, a uniformity of material grain size was achieved. The detail parts demonstrated that precision forgings and extrusions can be effectively produced by the high energy rate process in fewer stages than required by the more conventional processes.

Machine operating parameters and safety regulations were established for the operation of the San Diego Dynapak unit.

BLANK PAGE

| <u>TABLE OF CONTENTS</u> | <u>PAGE</u> |
|--|-------------|
| ABSTRACT | i |
| SUMMARY | ii |
| INTRODUCTION | 1 |
| CONCLUSIONS AND RECOMMENDATIONS | 1 |
| <u>General</u> | 1 |
| <u>Machine</u> | 1 |
| <u>Tooling</u> | 2 |
| DEVELOPMENT OF THE PROJECT | |
| <u>The Dynapak Machine and It's Operating Principles</u> | 2 |
| <u>Parts Manufacture</u> | |
| Selection of Parts | 13 |
| Manufacture | 17 |
| Lubricants | 31 |
| <u>Tooling</u> | |
| Design | 32 |
| Forging | 35 |
| Forward Extrusions | 42 |
| Backward Extrusions | 53 |
| Compacting | 57 |
| Materials | 59 |

GENERAL DYNAMICS/CONVAIR

TABLE OF CONTENTS
(Cont'd)

| | <u>PAGE</u> |
|---------------------------------------|-------------|
| <u>APPENDIX</u> | 61 |
| MACHINE OPERATING INSTRUCTIONS | |
| <u>General Operating Instructions</u> | |
| Safety Precautions | 63 |
| Test Firing | 64 |
| Machine Malfunction | 70 |
| Tool Installation | 72 |
| ACKNOWLEDGMENTS | 77 |

GENERAL DYNAMICS/ELECTRONICS

LIST OF ILLUSTRATIONS

| | <u>PAGE</u> |
|---|-------------|
| FIGURE 1 - SAN DIEGO DIVISION MODEL 1200 DYNAPAK INSTALLATION | 3 |
| FIGURE 2 - SAN DIEGO DIVISION MODEL 1205 DYNAPAK ILLUSTRATION | 4 |
| FIGURE 3 - MODEL 1205 DYNAPAK MACHINE FRAME MODIFICATION FOR 3RD SHOCK INSTALLATION | 6 |
| FIGURE 4 - CLOSE-UP OF "V" GROOVED MAIN RODS AND SQUARE BOLSTER PLATE | 7 |
| FIGURE 5 - CLOSE-UP OF SQUARE GROOVED MAIN RODS AND ROUND BOLSTER PLATE | 8 |
| FIGURE 6 - 1205 SERIES DYNAPAK MACHINE SCHEMATIC | 9 |
| FIGURE 7 - DYNAPAK AT REST AFTER POWER STROKE | 10 |
| FIGURE 8 - HYDRAULIC OIL RETURNS PISTON AND COCKS HYGE TRIGGER UNIT | 11 |
| FIGURE 9 - MACHINE READY TO FIRE | 12 |
| FIGURE 10- TRIGGER GAS ABOUT TO MOVE HYGE PISTON | 14 |
| FIGURE 11- DYNAPAK REACTION FRAME IN OPERATION | 15 |
| FIGURE 12 -FORGED SPRING TAIL HOOK FITTING AND BILLET(P/N 8-78732-7) | 16 |
| FIGURE 13- DYNAPAK FORGED ALUMINUM (2014) CLIP | 18 |
| FIGURE 14- DYNAPAK FORGED SAE 4130 BUSHING P/N 8-16512 | 19 |
| FIGURE 15- DYNAPAK FORGED SAE 4340 BUSHING | 20 |
| FIGURE 16- OPEN BACK EXTRUSION SAMPLES | 21 |
| FIGURE 17- FOREWARD EXTRUSION SAMPLE | 22 |
| FIGURE 18- INITIAL SPRING TAIL HOOK TOOLING | 23 |
| FIGURE 19- EXAMPLE OF MATERIAL SEPARATION | 24 |
| FIGURE 20- PHOTOMICROGRAPH OF TAIL HOOK FITTING STRUCTURE AS FORGED | 26 |

GENERAL DYNAMICS/CONVAIR

LIST OF ILLUSTRATIONS

| | <u>PAGE</u> |
|---|-------------|
| FIGURE 21 - PHOTOMACROGRAPH OF SAE 4130 P/N 8-16512 WING SPAR BUSHING | 28 |
| FIGURE 22 - PHOTOMICROGRAPH (200X) OF BILLET MATERIAL GRAIN SIZE 7 FOR 8-16512 BUSHING | 30 |
| FIGURE 23 - PHOTOMICROGRAPH (200X) OF 8-16512 BUSHING GRAIN SIZE SMALLER THAN 8 | 30 |
| FIGURE 24 - TYPICAL CLOSED FORGING DIE CROSS SECTION | 33 |
| FIGURE 25 - TYPICAL POCKET BLEED HOLE | 34 |
| FIGURE 26 - UNSTRESSED UNIVERSAL DIE HOLDER | 36 |
| FIGURE 27 - TYPICAL FORGE DIE DESIGN FOR UNSTRESSED DIE HOLDER | 37 |
| FIGURE 28 - UNIVERSAL HOLDER & STRIPPER RING | 40 |
| FIGURE 29 - BASIC HOLDER LESS STRIPPER RING | 41 |
| FIGURE 30 - BASIC HOLDER WITH STRIPPER RING IN UP POSITION | 43 |
| FIGURE 31 - TYPICAL BUSHING TOOLING | 44 |
| FIGURE 32 - FIRST PUNCH HOLDER BUILT | 46 |
| FIGURE 33 - PUNCH HOLDER FAILURE | 47 |
| FIGURE 34 - UNIVERSAL PUNCH HOLDER | 48 |
| FIGURE 35 - PRE-STRESSED EXTRUSION TOOL HOLDER | 49 |
| FIGURE 36 - TYPICAL FAILURE OF HIGH HARDNESS PUNCH | 51 |
| FIGURE 37 - TYPICAL UPSET FAILURE OF PUNCH | 52 |
| FIGURE 38 - EXTRUSION DIE BUTTON DESIGN | 54 |
| FIGURE 39 - EXTRUSION DIE BUTTON | 55 |
| FIGURE 40 - OPTIMUM BACK EXTRUSION PUNCH DESIGN | 56 |
| FIGURE 41 - FLATTENING DIES FOR COMPACTION ATTEMPT | 58 |
| FIGURE 42 - OPERATING CONSOLE CONTROLS | 66 |

GENERAL DYNAMICS/CONVAIR

INTRODUCTION

Preliminary work conducted under RMDA SD-9-8 at the Pomona Dynapak site and the Precision Forge Company facility in Santa Monica, indicated that conventional forging and extrusion practices were not entirely applicable to the high energy rate process. Consequently upon the acquisition of the Model 1200 series Dynapak machine by Convair-San Diego this project was initiated.

The purpose of this project was the establishment of tooling and operating parameters as well as part design limitations consistent with the high energy rate Dynapak forging process.

CONCLUSIONS AND RECOMMENDATIONS

General

The use of the Dynapak high energy rate process for forging and extrusion of metals is not only feasible but can be accomplished with closer tolerances and fewer stages than conventional processes.

Machine

It is recommended that the machine be "beefed up", to harness the tremendous forces generated, for production usage.

Ram guides should be further improved to provide accuracy and ram stability not available on present machines.

Tooling

Under no circumstances should a tool be bolted to the bolster plate from below.

Never use anything less than 1 inch bolts for hold-down usage.

Tool hardness should never exceed R_c 50 or go below R_c 46.

CONCLUSIONS AND RECOMMENDATIONS

Tooling (Cont'd)

Use an H-11 or equivalent shock resistant tool steel such as Durodi for part tooling. Do not use tool steels normally used for blanking and forming dies.

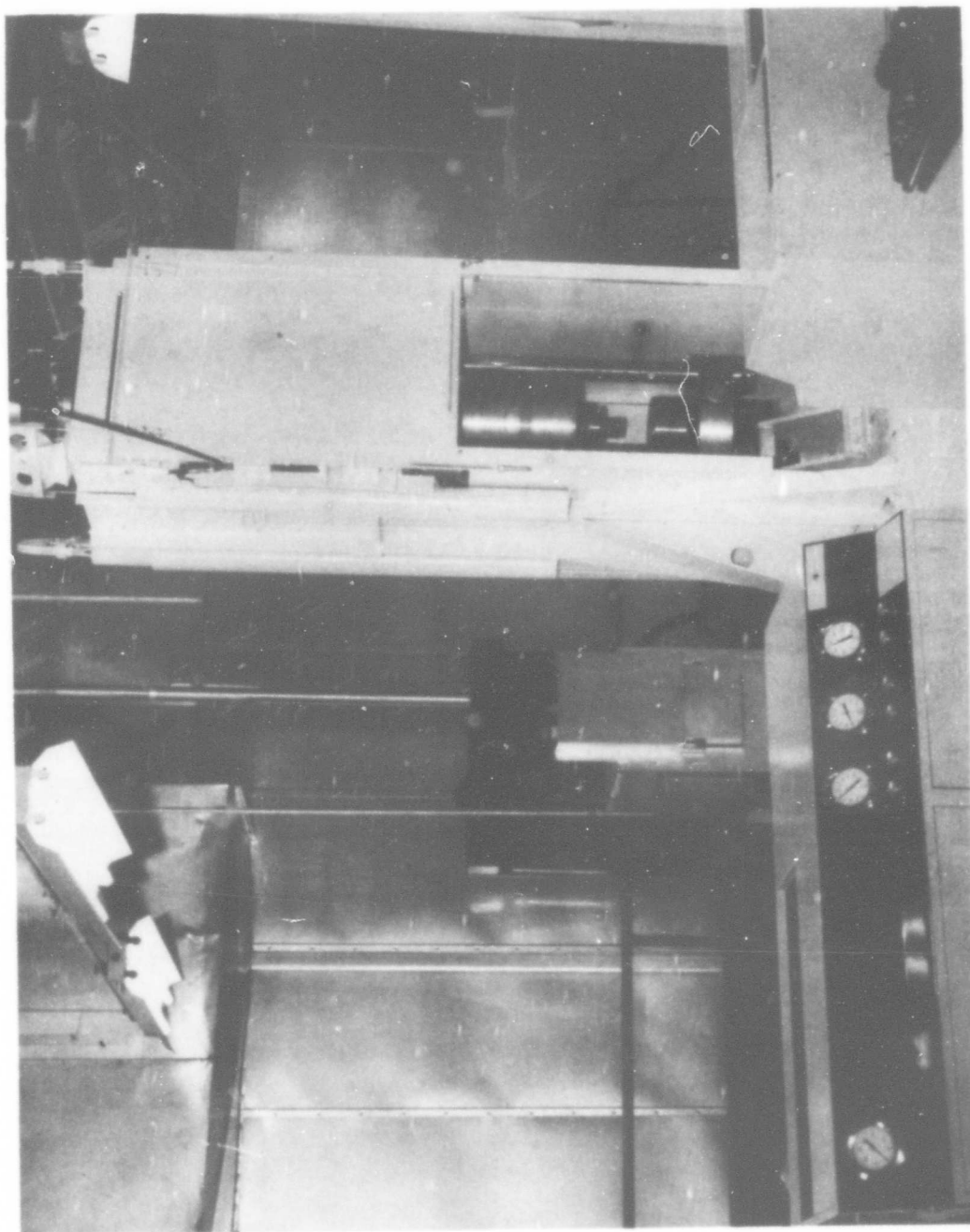
Maintain polished die surfaces to reduce the chances of material "pick up" during the operating cycle.

DEVELOPMENT OF THE PROJECT

The Dynapak Machine and It's Operating Principles

A Model 1200 Dynapak machine was utilized in the establishment of tooling and operating concepts. The original San Diego machine was adapted to operate in a vertical position since the machine was to be used in the forging application. An additional main rod foot arrangement was required to stabilize the machine since shock cylinders were mounted only on the two front main rods. Figure 1 illustrates the original unit as installed. The foot arrangement is seen beneath the bolster plate at the rear of the machine.

Initial work established that the machine was too lightly built to withstand constant forging operation. Information gained from the operation of the San Diego Division machine as well as others in the field resulted in machine modifications. A third shock cylinder was installed to eliminate the foot arrangement. All three shock cylinders were interconnected to insure a balanced gas pressure & uniformity of deflection. Square grooved main tie rods were replaced with "V" grooved units, and a heavier square bolster plate replaced the small round one. A front view of the modified unit is shown in Figure 2. A separate balance control console for shock cylinder pressures is mounted on the left side of the main frame of the machine.



Convair Photo 51311

Figure 1 - SAN DIEGO DIVISION MODEL 1200 DYNAPAK INSTALLATION

GENERAL DYNAMICS/CONVAIR

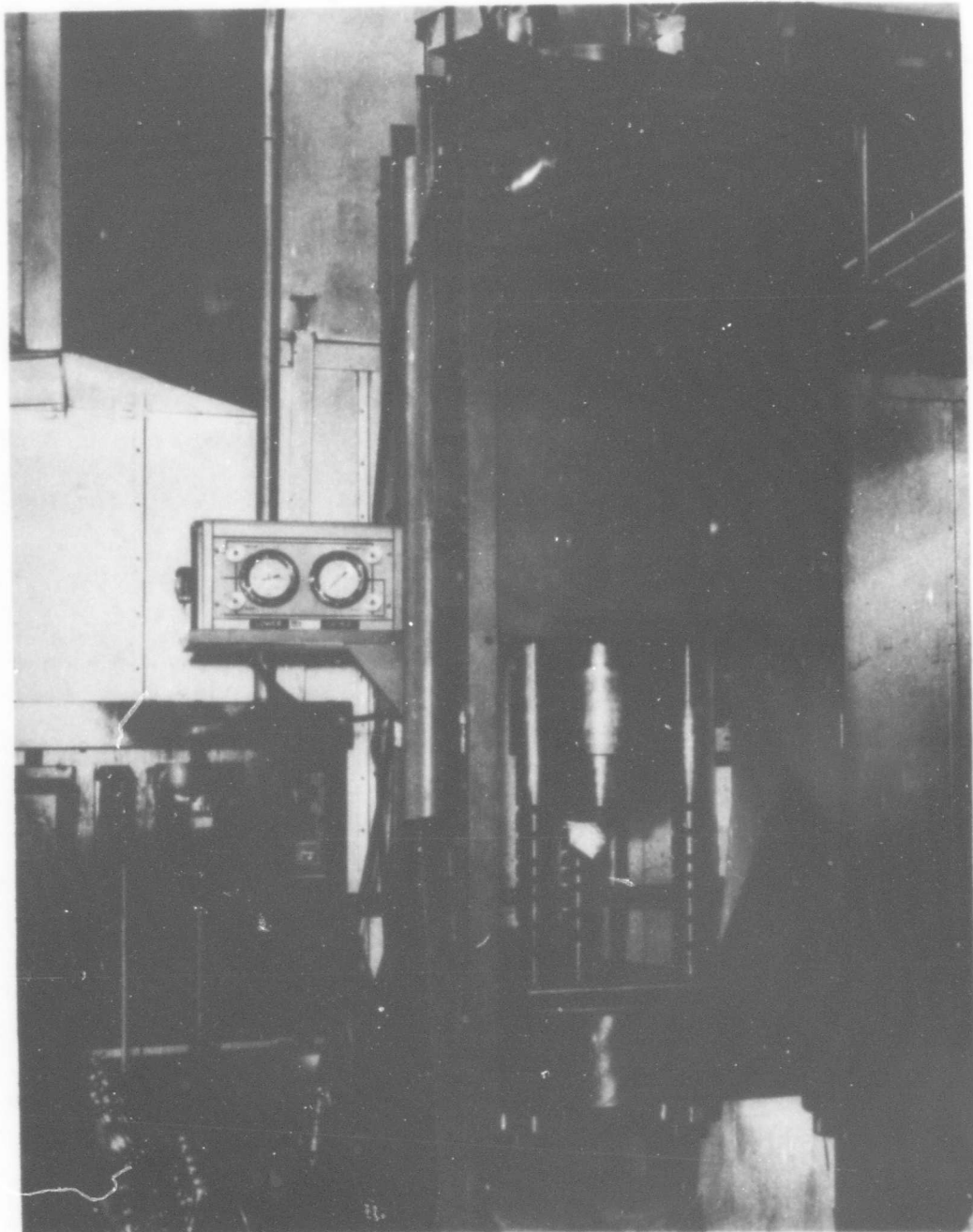


Figure 2 - SAN DIEGO DIVISION MODEL 1205 DYNAPAK INSTALLATION

Convair Print 62178

DEVELOPMENT OF THE PROJECT

The Dynapak Machine and It's Operating Principles(Cont'd)

A close-up of the modification of the main frame for the third shock cylinder can be seen in Figure 3. Figure 4 illustrates the change to "V" grooves on the main tie rods and the heavier square bolster plate which replaced the square grooved rods and small round bolster plate shown in Figure 5.

Figure 6 schematically illustrates the vertically mounted Dynapak unit. High pressure gas is stored in chamber A and low pressure gas in chamber B.

Illustrating the machine operation let us examine schematics of the various stages of the operating cycle. Figure 7 illustrates the unit in an "as fired" condition with the ram down. Recycling the machine is initiated by pumping hydraulic oil into chamber B. This forces the piston up to the orifice plate seal ring and simultaneously recompresses the gas into chamber A. The hydraulic pump then forces the double piston in the trigger unit in chamber A down against the orifice plate seal ring. These operations are shown completed in Figure 8. When both pistons are seated the gas trapped in the hole through the orifice plate between them is exhausted to the atmosphere. In the next step shown in Figure 9 the hydraulic oil is forced out of piston back-up areas by compressed gas at a pre-determined pressure. It should be noted that the pressure behind the ram piston is not identical to that separating the trigger unit pistons. The reasons for this are discussed in the operating instructions section. The machine is ready to fire at this point. It is only necessary to over-balance the lower trigger piston by admitting a spurt of high pressure gas

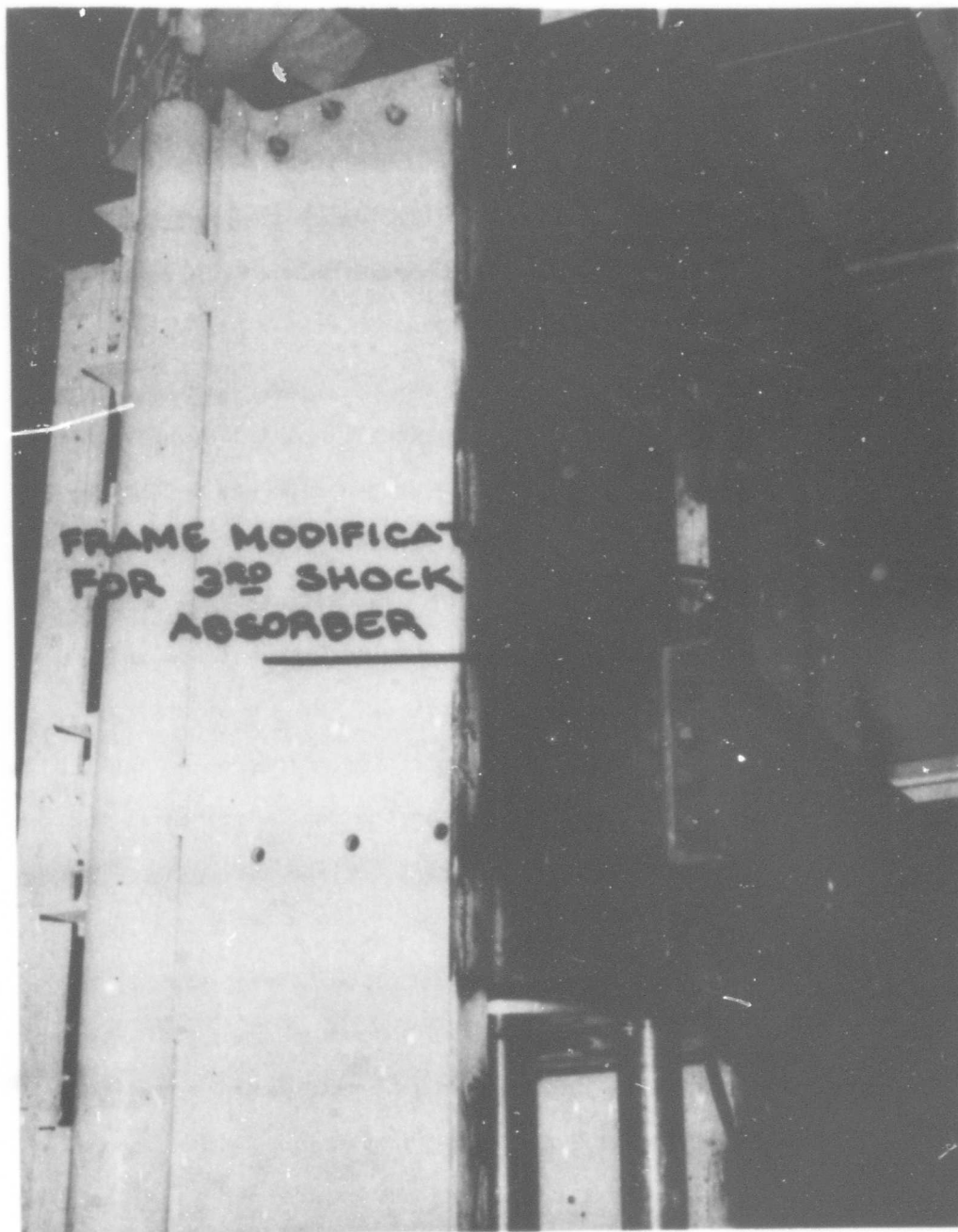


Figure 3 - MODEL 1205 DYNAPAK MACHINE FRAME
MODIFICATION FOR 3RD SHOCK INSTALLATION

Convair Print 60581

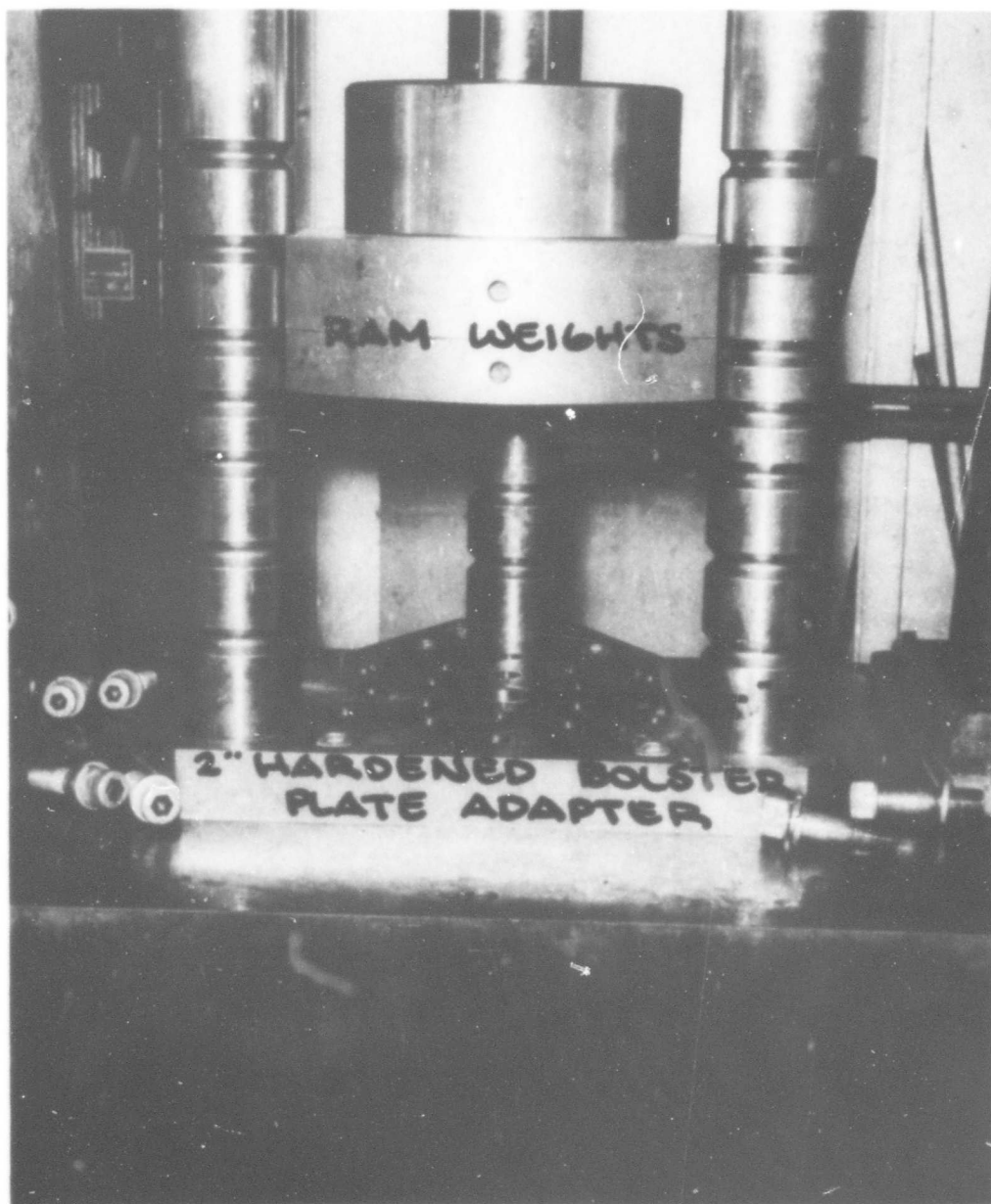


Figure 4 - CLOSE UP OF "V" GROOVED MAIN RODS AND SQUARE
BOLSTER PLATE

Convair Print 60580

GENERAL DYNAMICS/CONVAIR

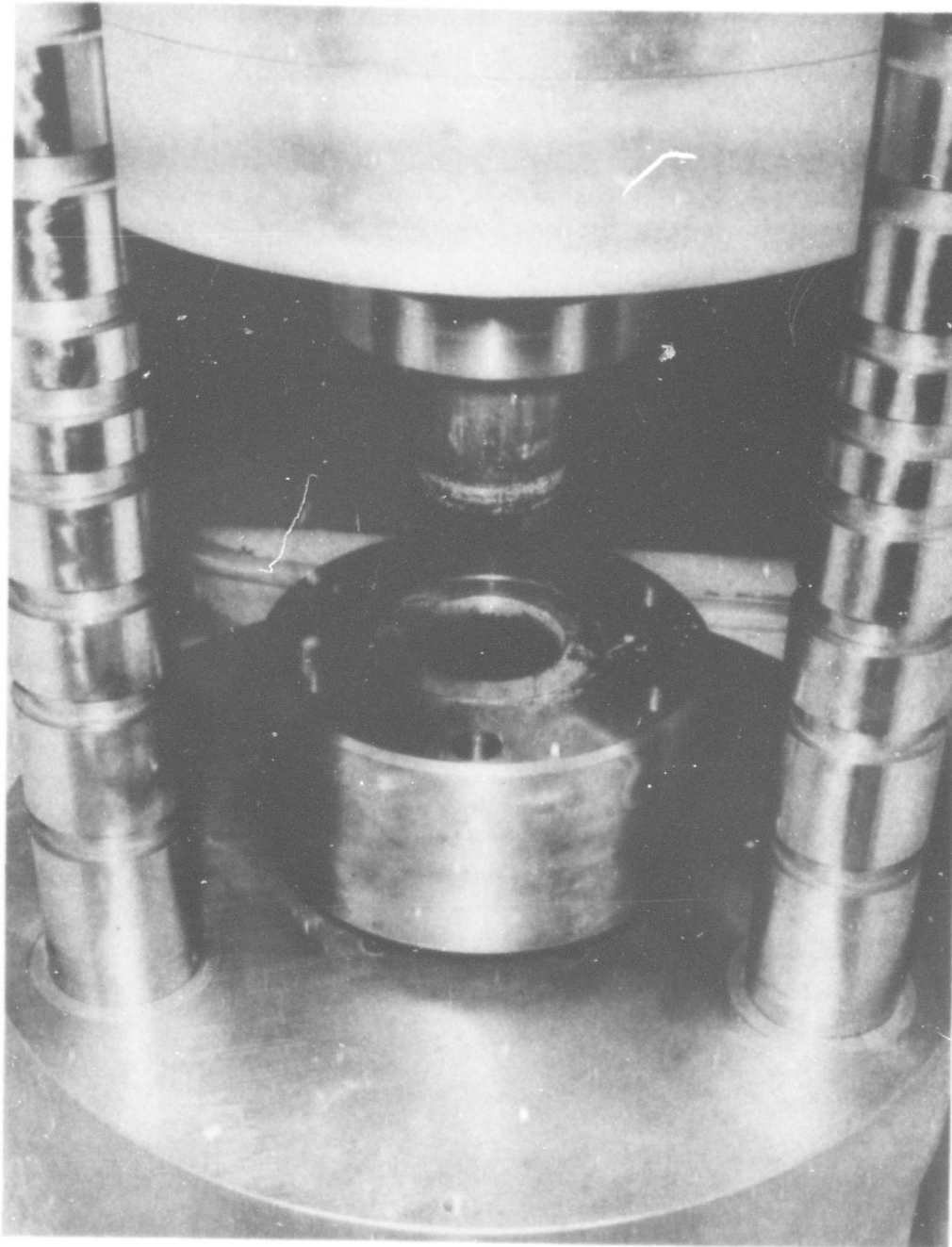


Figure 5 - CLOSE-UP OF SQUARE GROOVED MAIN RODS AND
ROUND BOLSTER PLATE

Convair Print 51322

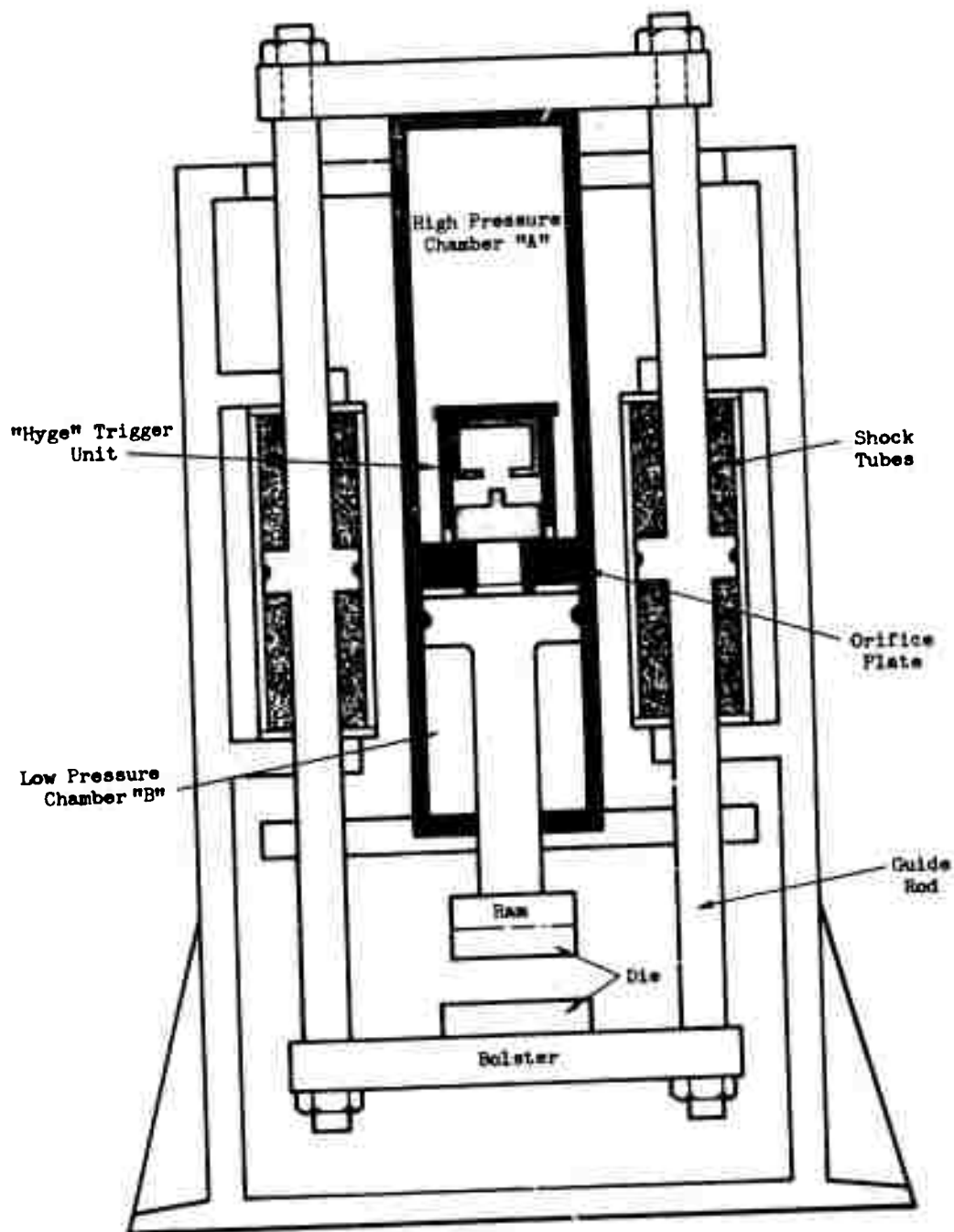


Figure 6 - 1205 SERIES DYNAPAK MACHINE SCHEMATIC

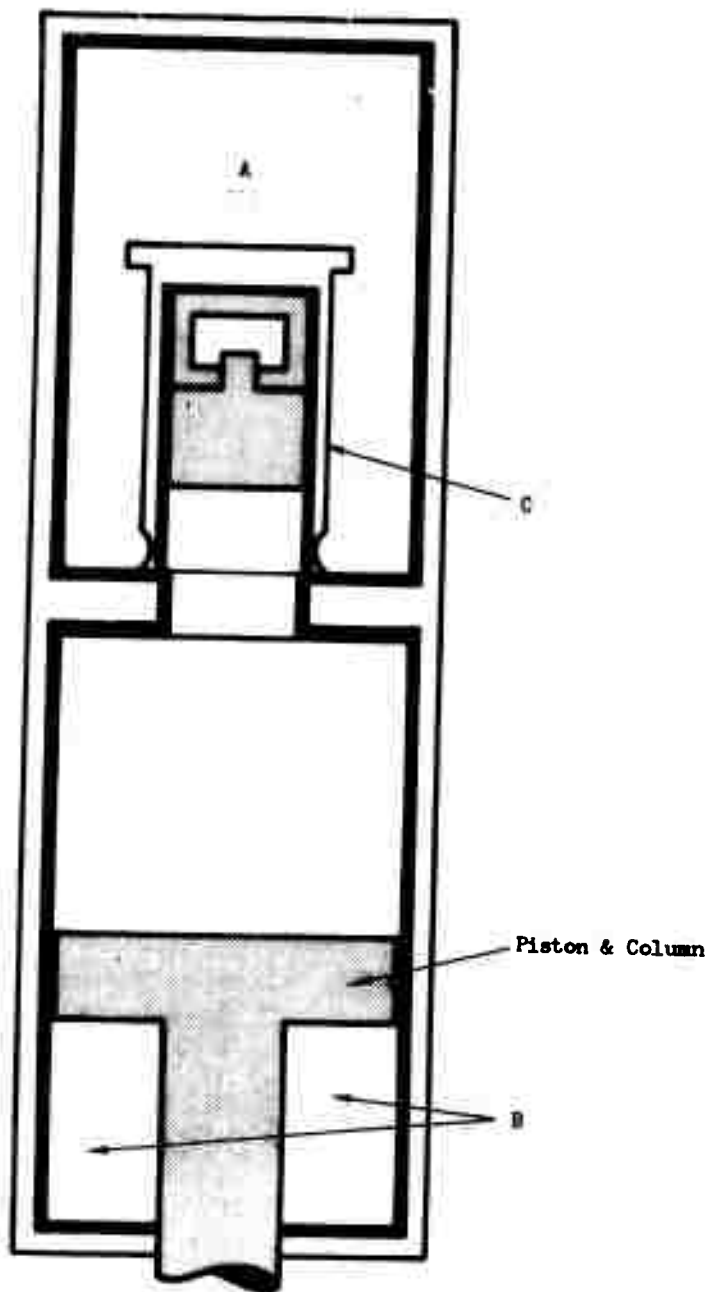


Figure 7 - DYNAPAK AT REST AFTER POWER STROKE
Convaiv Print 68818-7

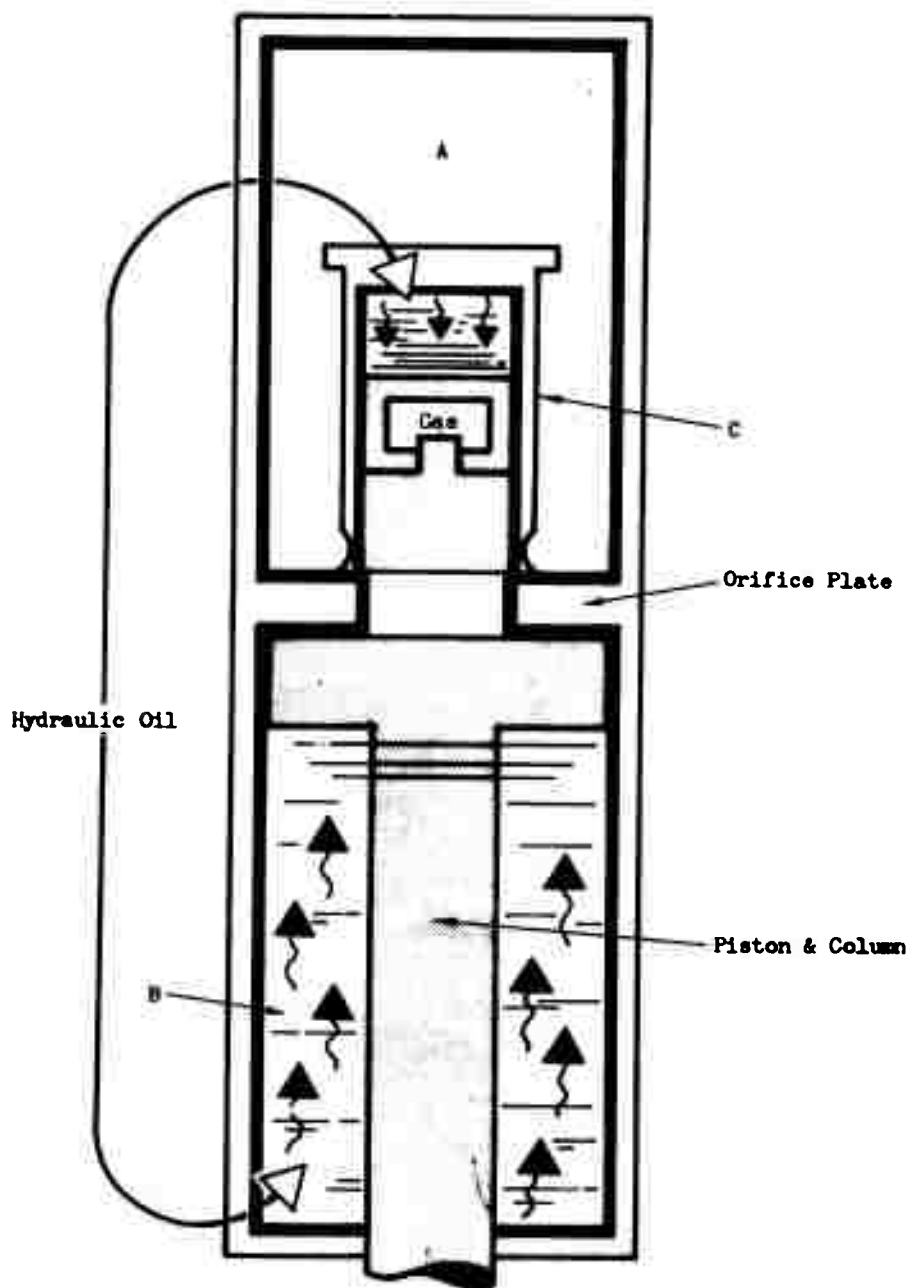


Figure 8 - HYDRAULIC OIL RETURNS PISTON AND COCKS HYGE TRIGGER UNIT
Convair Print 68818-8

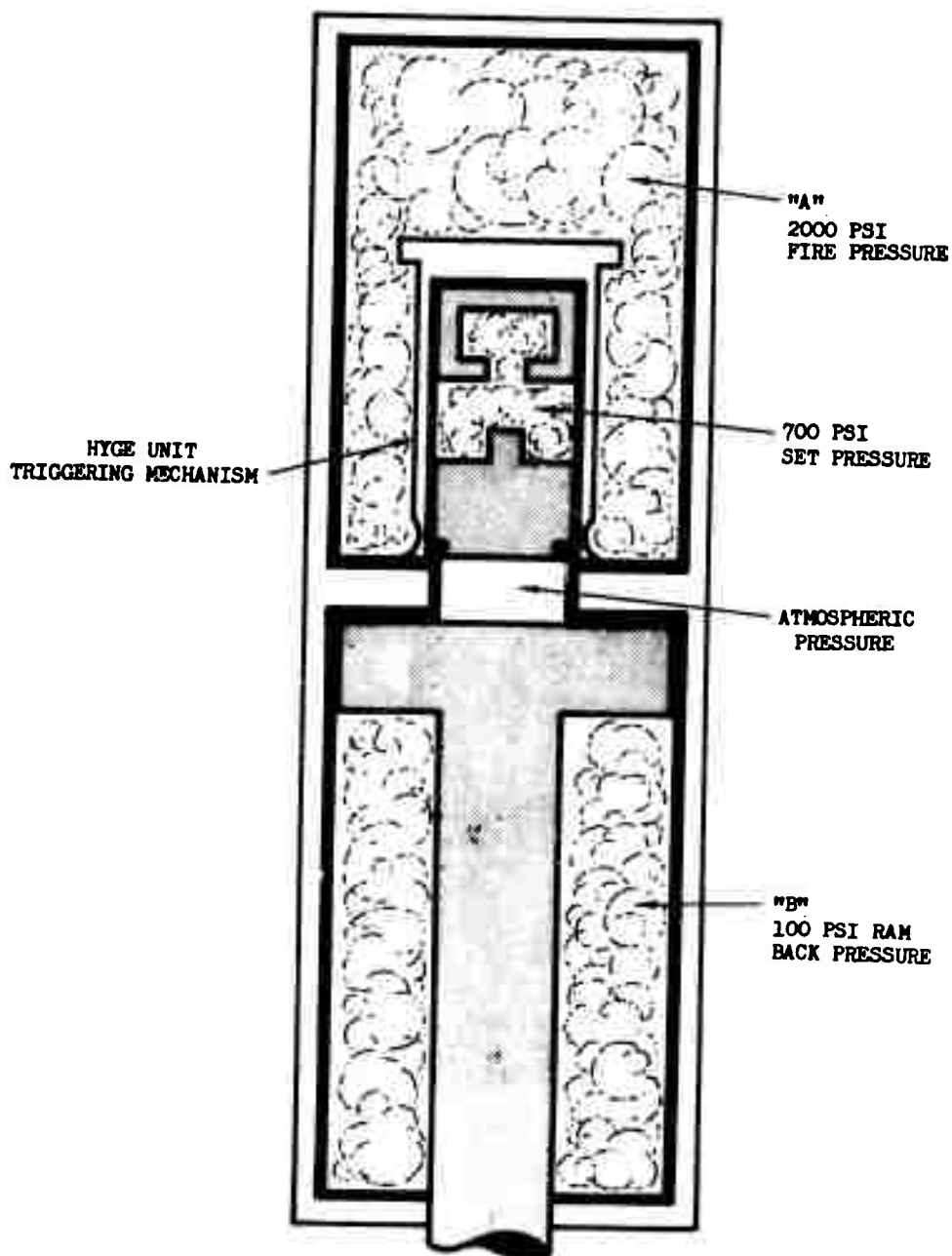


Figure 9 - MACHINE READY TO FIRE
Convair Print 68818-1

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

The Dynapak Machine and It's Operating Principles (Cont'd)

into the orifice areas as shown in Figure 10. This spurt of gas moves the small piston away from it's seat on the orifice plate and allows the high pressure gas in the upper cylinder to act against the ram piston driving it downward at high velocity. Note in Figure 11 that as the ram moves toward the bolster, the machine reacts in the opposite direction. The shock cylinders control machine reaction through their own piston system, as shown in Figure 6, thus preventing the forces from being transmitted to the floor. This unique feature allows the machine to produce exceptionally high impact forces and yet be installed without special floor mountings or pit arrangements required for conventional presses.

Parts Manufacture

Selection of Parts

Part selection was based principally on the type of process which would be required to produce the configuration. Although the primary objective of the project was the establishment of tooling and operating parameters, consideration was given in the selection of parts to potential cost reductions, should production of the selected part be desired.

Two details were selected to demonstrate and determine draftless forging techniques. The first part, an F-106 spring tail hook fitting (P/N 8-78832-7) of aluminum (2014) alloy, was chosen for its angularity and side wall to front wall thickness ratio. Figure 12 illustrates the forged detail and round billet from which it was formed. The second part was an aluminum (2014) clip (P/N 22-18892) which was used to determine the boundaries of

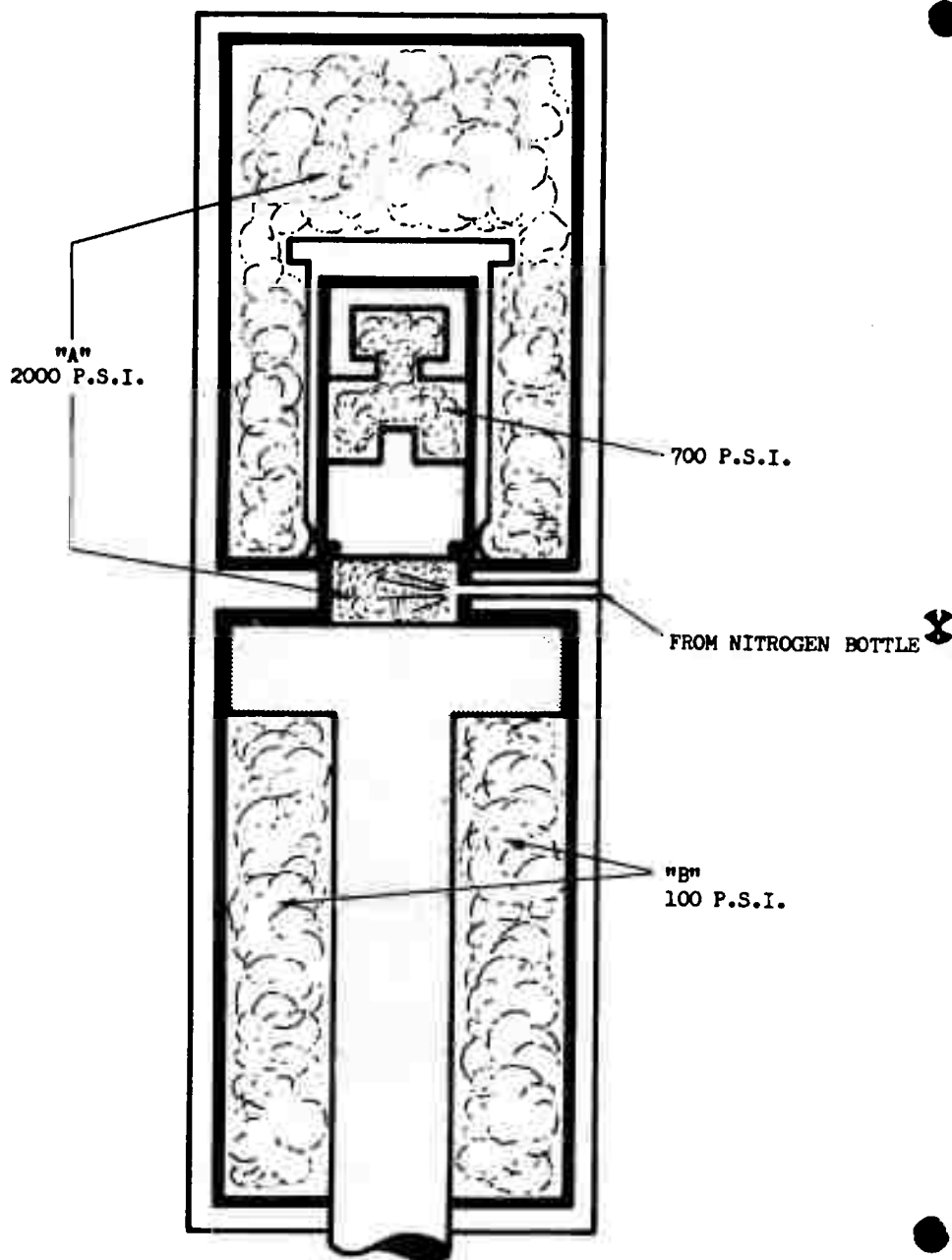


Figure 10 - TRIGGER GAS ABOUT TO MOVE HYGE PISTON
Convair Print 68818-2

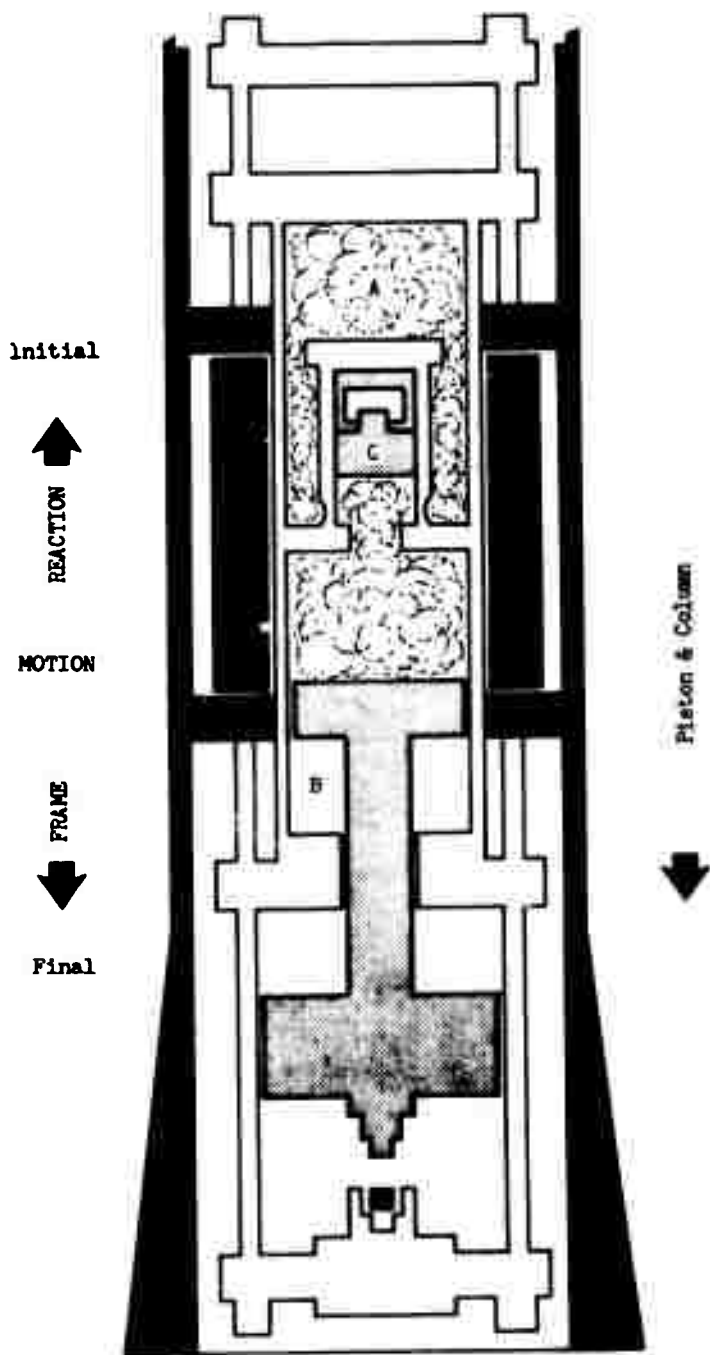
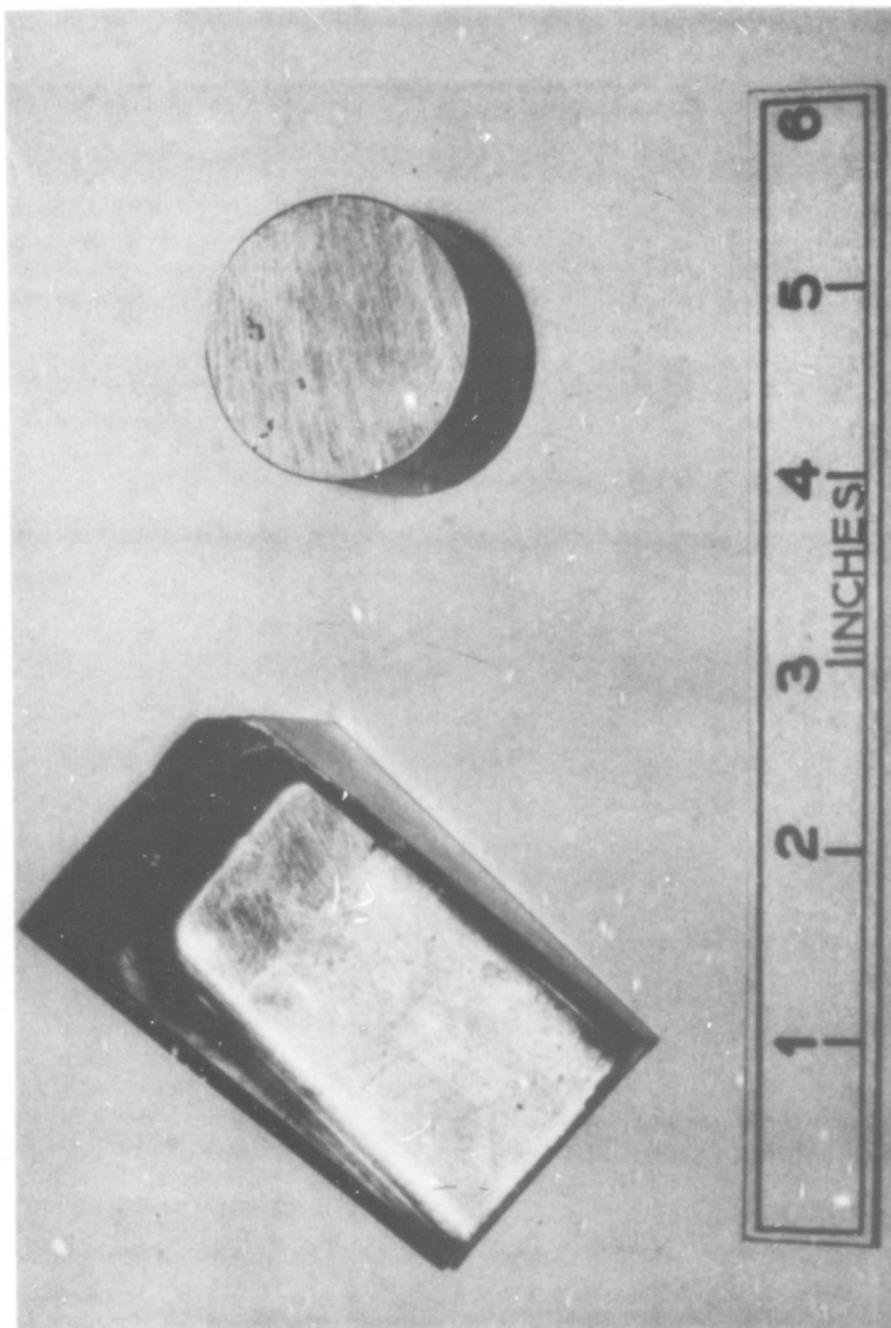


Figure 11 - DYNAPAK REACTION FRAME IN OPERATION
Convair Print 68818-4



FORGED PART AND BILLET
P/N 8-78732-7

Figure 12 - FORGED SPRING TAIL HOOK FITTING & BILLET
(P/N 8-78732-7)

Convair Print 57008

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Parts Manufacture

Selection of Parts (Cont'd)

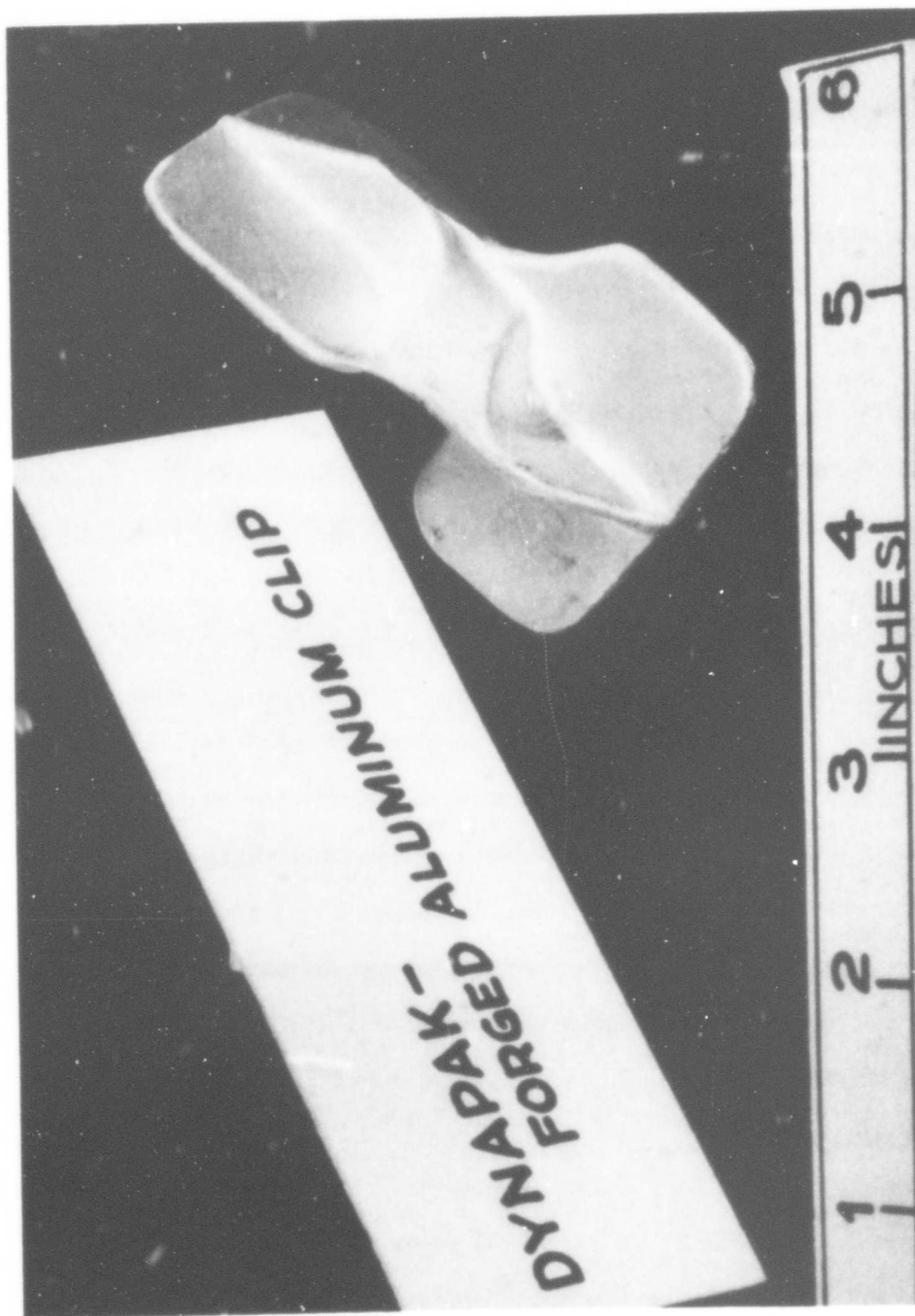
draftless thin wall forged details. Figure 13 illustrates the forged detail after trimming.

Two details demonstrating closed forging techniques were selected. The first selection was a small diameter deep cup and the second was a large diameter shallow cup. It should be noted that the cup bottom is removed in a machining operation. The small diameter bushing P/N 8-16512) made from SAE 4130 steel is shown with the initial billet in Figure 14. The second detail made from SAE 4340 steel is shown in Figure 15.

In addition to the forging applications previously mentioned, an open back extrusion test part was made to examine tool characteristics. The test pieces are shown in Figure 16. Forward extrusion tooling techniques were also evaluated. The cruciform shown in Figure 17 is an example of the test parts produced. Deformation of the extrusion resulted from contact with the floor, illustrating the impracticability of extruding with the machine mounted vertically and without special provisions for extrusion length.

Manufacture

The F-106 tail hook detail P/N 8-78732-7 being the first part selected... was the basic trial part for both machine operation and forging evaluation. The initial tooling made from SAE 52100 tool steel and heat treated to RW/c 48-50 did not prove to be sufficiently shock resistant for general usage. Figure 18 illustrates the cracked female die. It should be



Convair Print 403-61

Figure 13 - DYNAPAK FORGED ALUMINUM (2014) CLIPS

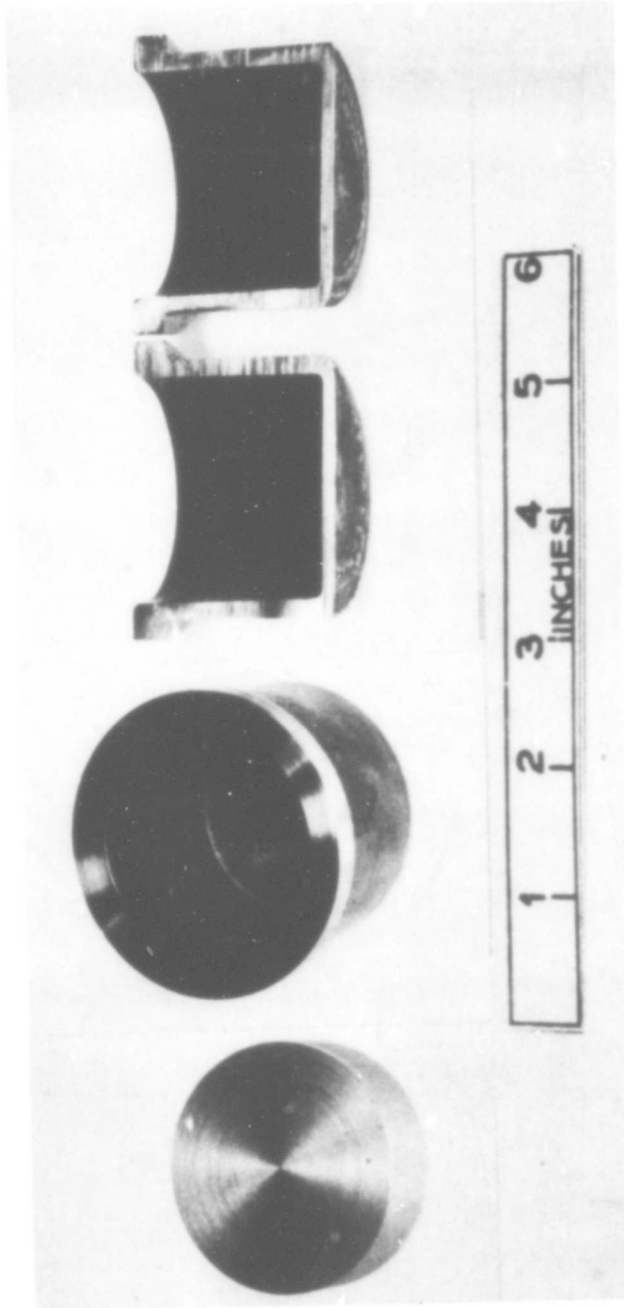
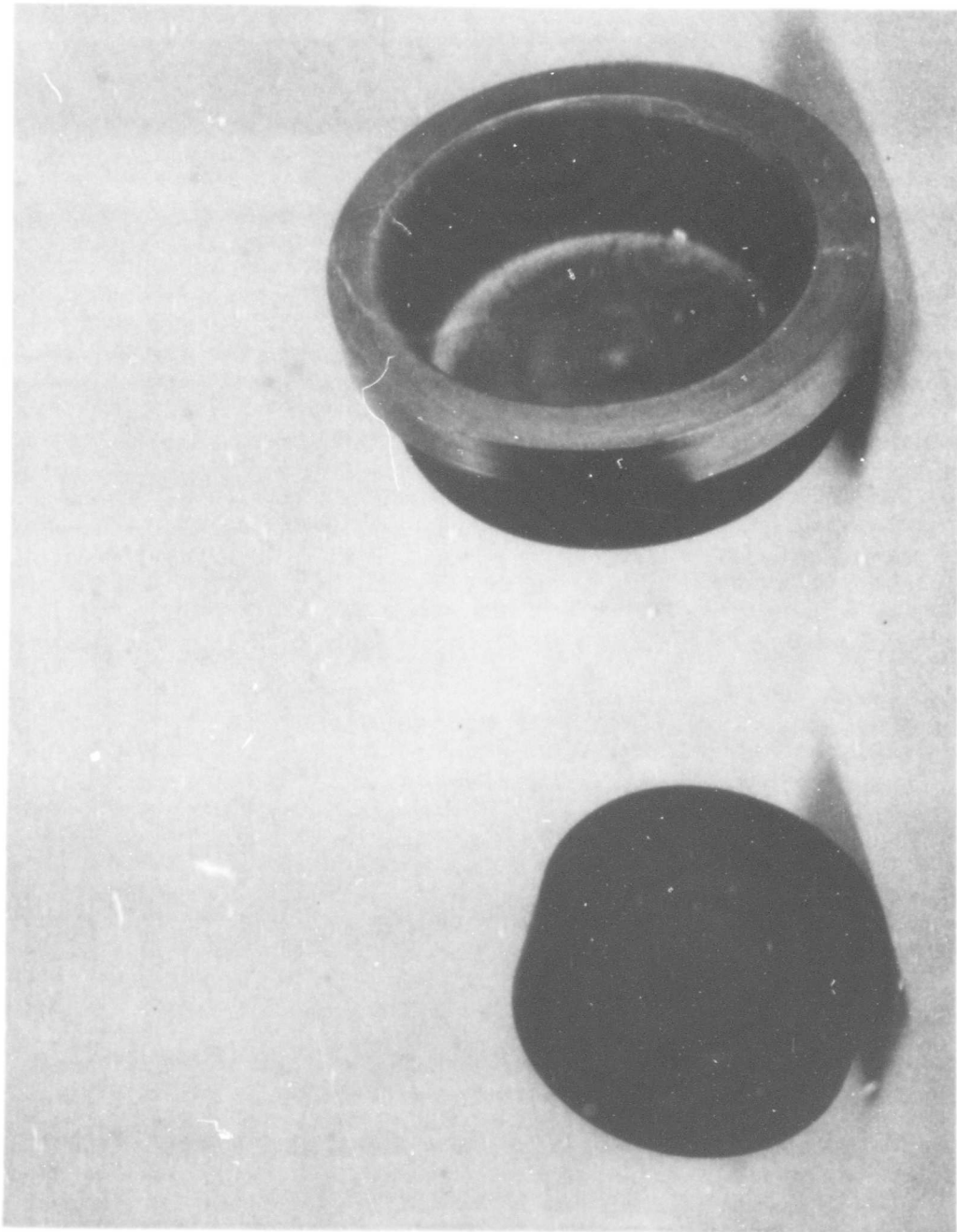
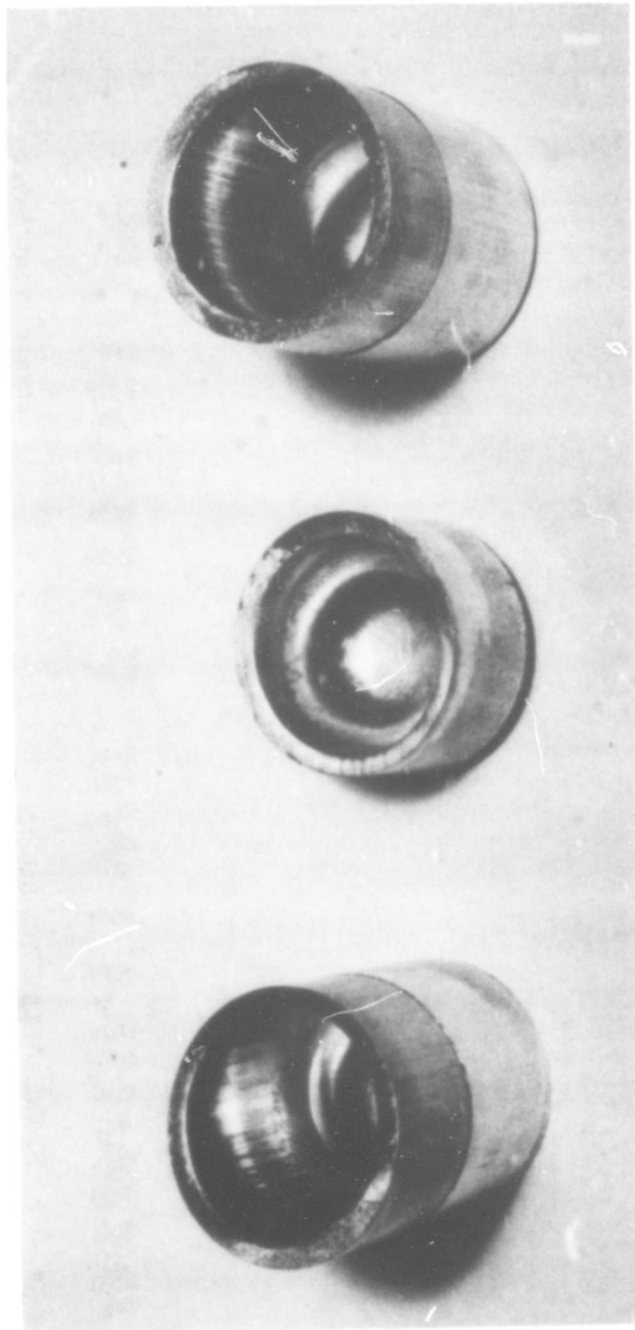


Figure 14 - DYNAPAK FORCED SAE 4340 BUSHING P/N 8-16512 Convair Print No. 57334



Convair Print 51616

Figure 15 - DYNAPAK FORGED SAE 4340 BUSHING



ALUMINUM BACK EXTRUSION

Convair Print 54925

Figure 16 - OPEN BACK EXTRUSION SAMPLES



ALUMINUM FWD. EXTRUSION

Figure 17 - FOREWARD EXTRUSION SAMPLE

Convair Print 54922

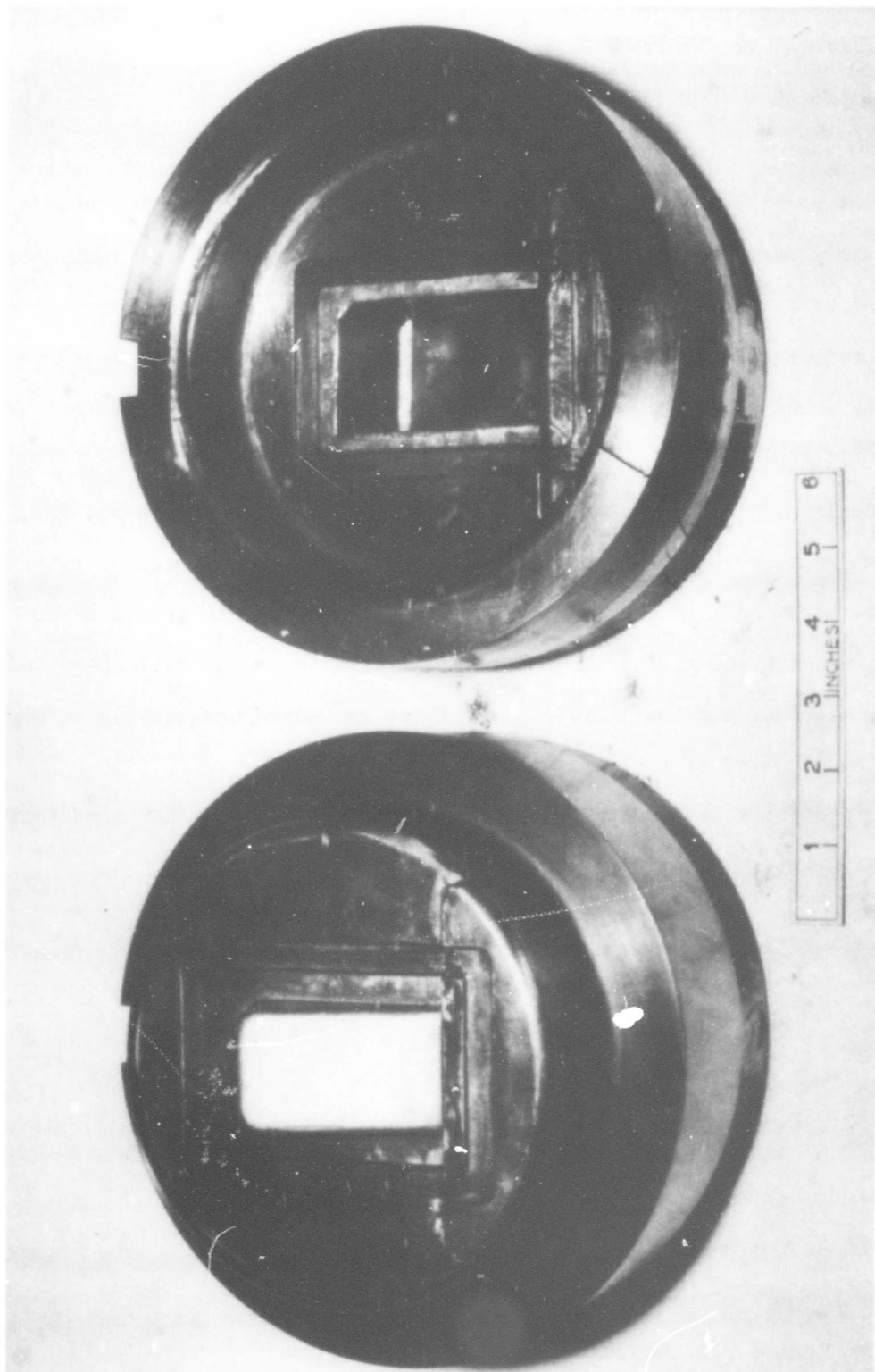


Figure 18 - INITIAL SPRING TAIL HOOK TOOLING

Convair Print 57007

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Manufacture (Cont'd)

noted that the female die, contrary to general practice, was not radiused in the corners. This was done to determine if such a design practice was feasible since many precision detail parts do not have large radii normally required for conventional forging practice.

A second female die was made from Durodi tool steel which proved to be quite successful. This steel heat treated to RW/c 48-50 outlasted the SAE 52100 male punch.

Preliminary efforts conducted with the required part material, 2014 Aluminum alloy, established the critical nature of the speed of material flow. It was found that without traps, built up in the trim area to restrain the material flow, the material mass tended to pull apart indicating that the momentum resulted in a force exceeding the tensile strength of the material at the particular temperature.

Considerable difficulty was experienced in the bottom flat area indicated in Figure 19.

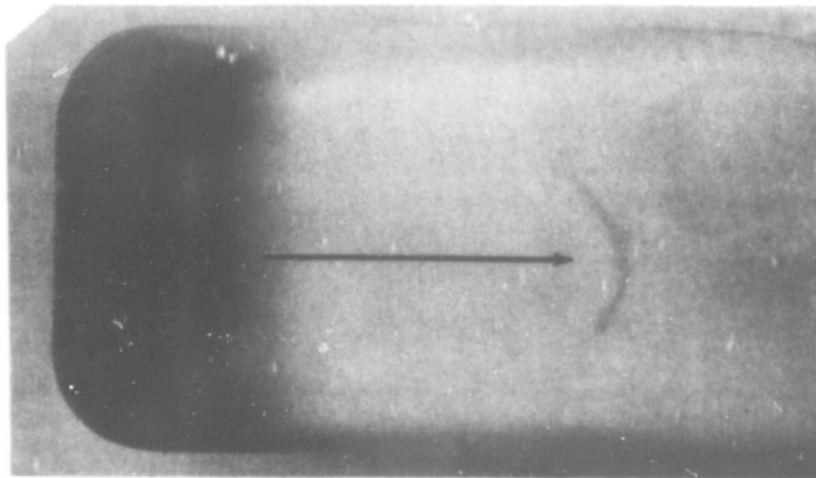


Figure 19 - EXAMPLE OF MATERIAL SEPARATION

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Trap areas were added to further restrain the material flow, with success. Billet configurations were altered in attempts to control the flow. Wedges, squares, rectangular and round billets were utilized. The round extruded billet material, it was found, provided the maximum amount of separation free parts.

Several difficulties were encountered which could be traced to machine functions. First the bounce or rebound encountered often trapped flash material and embedded it into the forged detail on the rebound hit. A second feature which caused trouble was the slow retraction of the ram after the forming stroke. Prolonged contact between the forged detail and the dies resulted in heat checks and short tool life. In addition, part shrinkage due to cooling resulted in parts contracting on the punch requiring heat to remove the part from the tool.

The forged fitting was produced in one operation requiring a secondary trim operation to remove flash. Part dimensions were to blue print specifications in all respects. Metallurgical examination revealed excellent flow characteristics in the vertical walls and bottom sections of the non-separated (round billet) parts as shown in Figure 20.

The aluminum clip (P/N 22-18892) was produced from a round billet (extrude' bar stock). Three different billet lengths were used in attempts to fill the tool cavity in one operation without success. An excessive length billet was then struck, trimmed and then restruck completely filling the cavity. The excessive depth to width relationship in the vertical fin areas was a source of trouble in two ways. First; since there was no draft allowance on one face; there was a predominate tendency for the metal

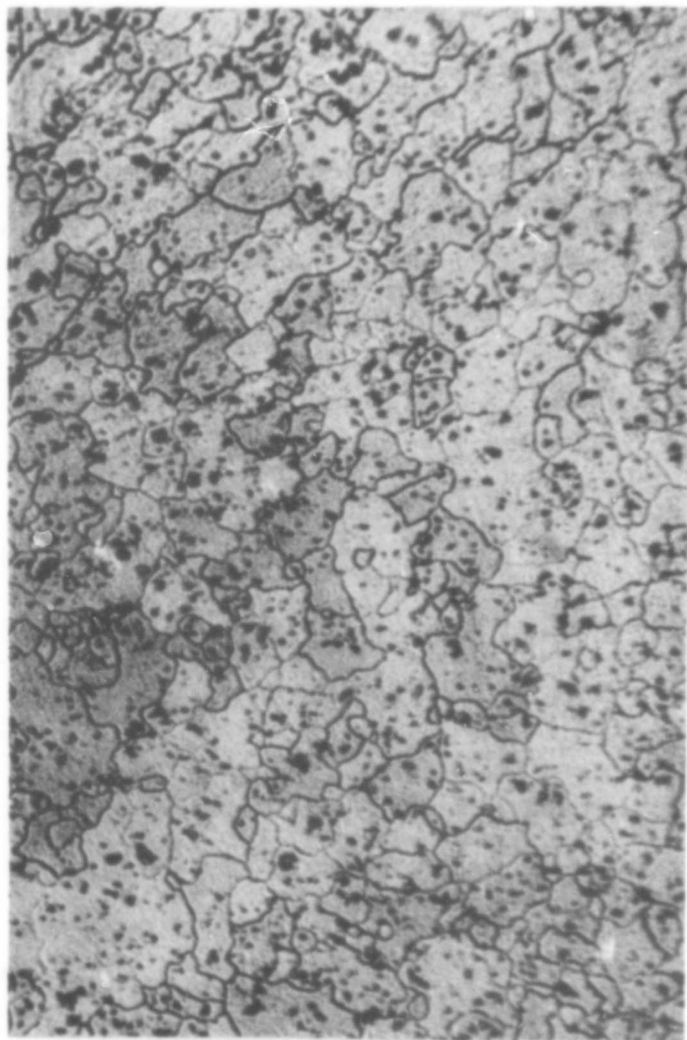


Figure 20 - PHOTOMICROGRAPH OF TAIL HOOK FITTING STRUCTURE
AS SHOWN

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

to stick in the die cavity. Second; the machine bounce coupled with the tendency of the material to stick in the die cavity frequently tore the forged detail in half.

Various lubricants were used to provide less friction in the vertical fin areas but results were unsatisfactory. Although the part can be made on the Dynapak machine without draft on the deep fin areas, the scrap rate is excessive. Therefore it is concluded that draft will have to be added to achieve production efficiency.

A wing spar bushing (P/N 8-16512) was the first production forging attempted in a closed die. Tooling was designed to include a floating stripper arrangement which was also a portion of the closed die cavity. A complete discussion of the particular tool is found in the tooling section.

SAE 4130 steel was used for the first time in the forging evaluation in producing this part. Some scaling was encountered due to lack of atmospheric control in the billet heating furnace. For the most part the billets were heated to approximately 2100 F for effective material flow. Scale formed during the heating, to forging temperature, was removed by a sharp blow against the bolster prior to positioning the billet in the die opening. Excess material was left in all areas for final machining and grinding. It is believed that if adequate furnace controls were available, net parts could be produced since allowances would not have to be made for removal of scaled areas by machining operations.

Engineering Laboratory Analysis was made on representative parts. Photomicrographs of sectioned parts indicated that flow characteristics in the vertical wall were satisfactory (Figure 21.)

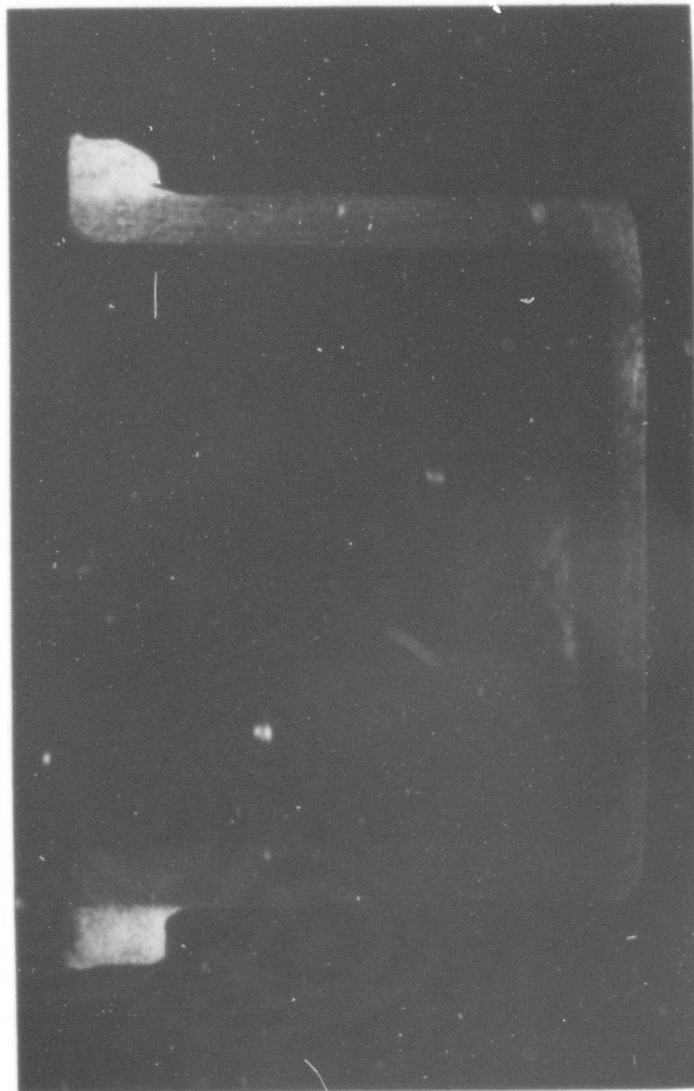


Figure 21 - PHOTOMICROGRAPH OF SAE 4130 PN 8-16512 WING SPAR BUSHING
ENGINEERING TEST LAB 0-1812

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Flow in the bottom of the cup could be improved through tooling modifications but since this area was to be cut away in these parts, no attempt was made to rework the tooling. The flange area shown on the right side of Figure 21 illustrates a lap; indicating flow problems in this area. A modification of the radius in the area of the lap to provide better flow would be required if the flange is to be produced without excess clean-up stock.

Photomicrographs taken of both the billet and the finished part illustrate the marked reduction of grain size achieved in the Dynapak operation. Figure 22 shows the grain size of the billet at 200 x and Figure 23 shows the grain size of the forged part at 200 x.

Mechanical property tests showed that the Dynapak part as forged was approximately equal to the properties of the hardened and tempered non-forged material. The results are as follows:

Dynapak as forged

| | |
|----------------------|------------------|
| 198,500 psi ultimate | 20% elongation |
| 190,900 psi ultimate | 17.5% elongation |

Billet - hardened and tempered

| | |
|----------------------|----------------|
| 191,500 psi ultimate | 25% elongation |
|----------------------|----------------|

Dynapak - hardened and tempered

| | |
|----------------------|----------------|
| 187,700 psi ultimate | 10% elongation |
| 176,000 psi ultimate | 20% elongation |

The hardened and tempered Dynapak part, however, fell short of the hardened and tempered properties of the non-forged material. Further evaluation will have to be made to verify the above findings if it is desired to eliminate further heat treatment of Dynapak forged parts.

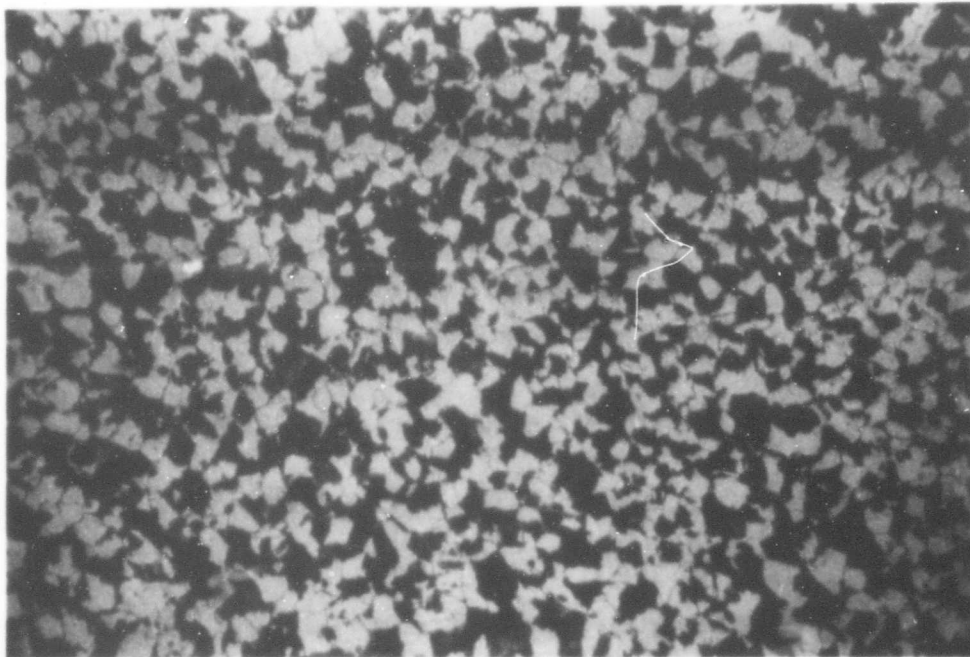


Figure 22 - PHOTOMICROGRAPH (200X) OF BILLET MATERIAL
GRAIN SIZE 7 FOR 8-16512 BUSHING

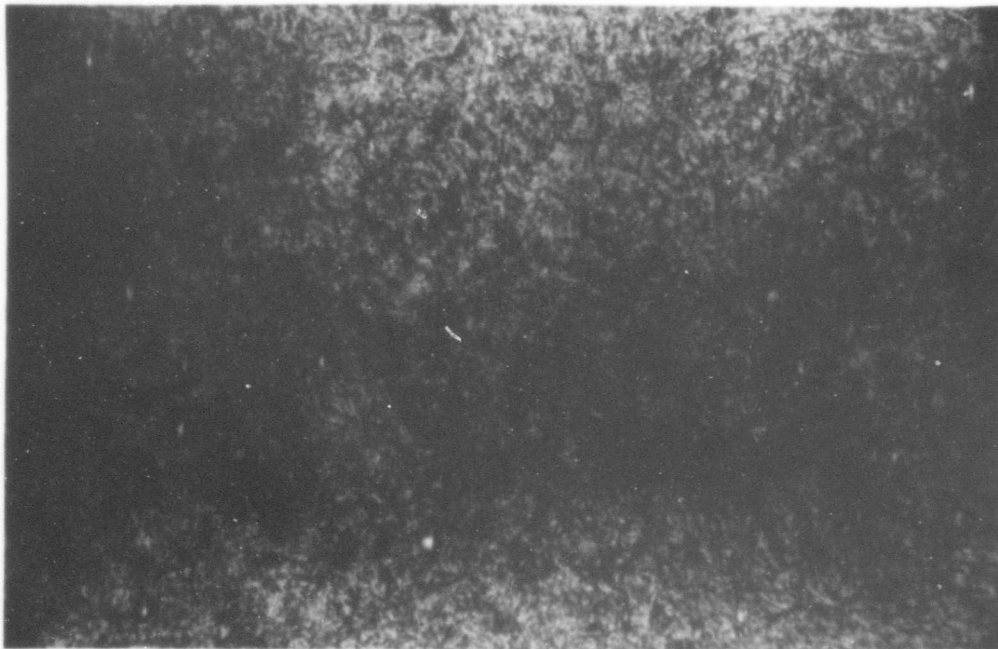


Figure 23 - PHOTOMICROGRAPH 200X OF 8-16512 BUSHING
GRAIN SIZE SMALLER THAN 8.

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Repair bushing 22-51001 (REQ 1660) also utilized the universal die holder and punch holder. AISI 4340 steel used in the part presented the same scale problems as were encountered with the SAE 4130 evaluation. Again most of the scale flowed into the flash area where it was removed in the rough trimming operations. The remaining scale was on the part surfaces where allowances had been made for finish machining and consequently did not present any problems. Flow characteristics were basically the same as encountered in the previous bushing indicating that the size difference was of very little consequence.

Lubricants

Maintenance of a lubricating media between the part material and die material is essential in the Dynapak process. Poor lubrication leads to galling of punches and dies and increased tool loadings. In addition it can also lead to the requirement of increased fire pressure and billet temperature. It also should be noted that lubricant ineffectiveness necessitates frequent tool polishing. Too much lubricant leads to a dieseling effect and die checking from high intensity local heat zones.

Of the lubricants tested, a mixture of peanut oil and graphite was found to be satisfactory for aluminum alloy forging. The use of higher temperatures for steels required a mixture of litharge and glycerine.

Lubricants ordered for evaluation did not arrive in time for testing but information obtained from other Dynapak users indicates that colloidal graphite dispersions (Dag dispersions) are effective in the 1800-2300 F forging range.

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Tooling

Design

(Forging-General Notes)

Forging die design is similar in many respects to press closed die forging design even though the Dynapak technique is more closely related to drop forging. Die blocks are not as large as the typical drop forging tool and in general are heat treated to R_c 48-50 in contrast to normal practice of R_c 45 maximum.

Due to press limitations, lead-in must be provided on forging dies to insure proper mating of punch and die upon impact. In general it was found that a one inch lead-in was required. Figure 24 illustrates a cross section of a typical closed forging die and the lead-in required. A secondary use of the "lead-in" is the prevention of side thrust in some part configurations. Parting lines, for punch & die, should be designed whenever possible to balance side thrust.

Closed, deep pocket areas where lubricants and air may be trapped during a forging cycle should, whenever possible, have small holes in the bottom area in which lubricant and air may be compressed without retarding the part material flow. Figure 25 illustrates such a pocket area and the bleed hole. Without such provisions the inherent high compression and dieseling effect may prevent the part from filling the die. The bleed hole may be either tapered or straight.

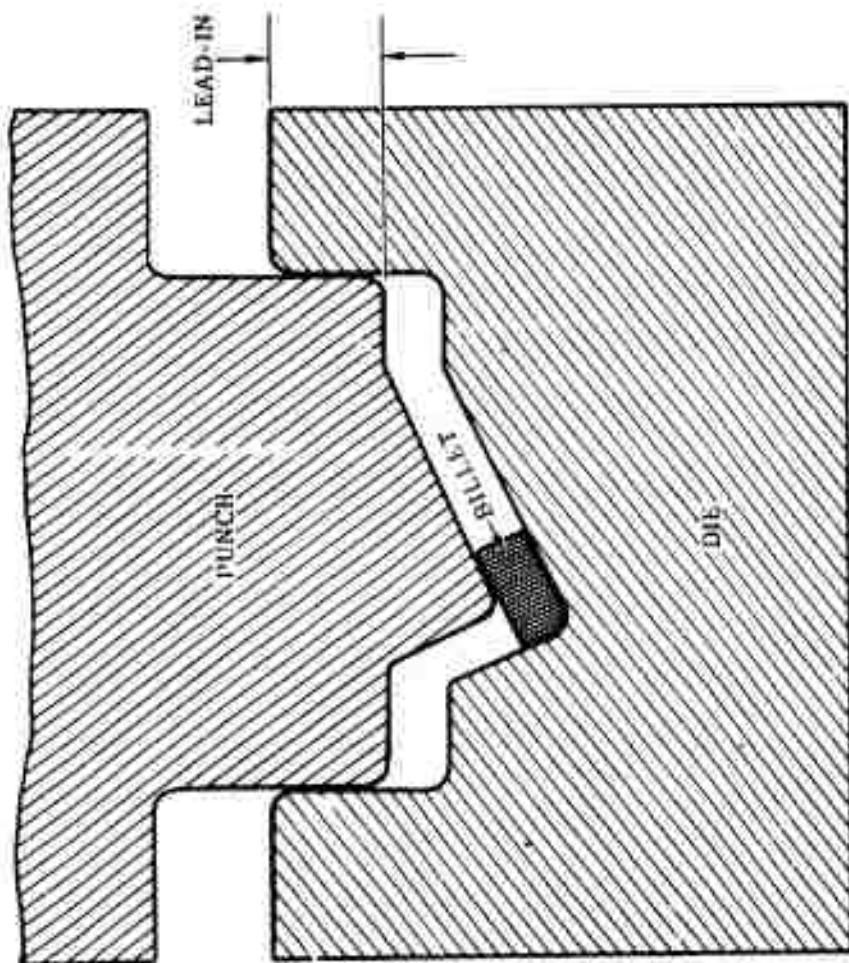


Figure 24 - TYPICAL CLOSED FORGING DIE CROSS SECTION

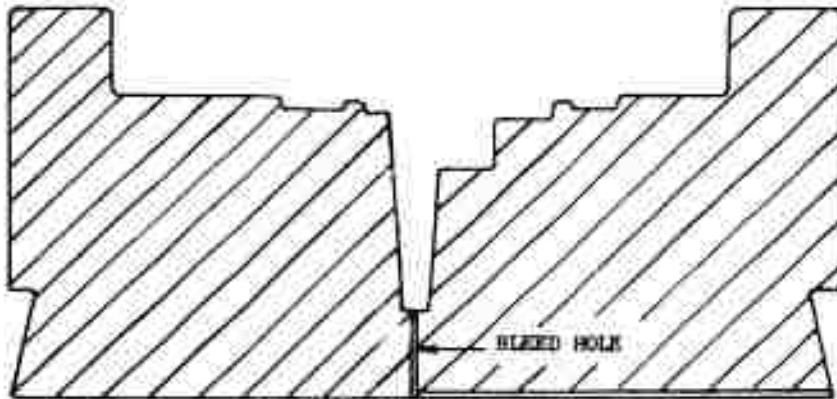


Figure 25 - TYPICAL POCKET BLEED HOLE

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

(Forging - Tool Development)

Two universal punch and die holders were developed to provide short tool change time and standardize forging tool block dimensions. The first basic type was unstressed, the second prestressed. The unstressed tool holders were used in all forging tests since detail part dies were made to fit the first set of holders.

The unstressed holders are satisfactory for a major portion of forging applications which fall within a four inch diameter circle. Larger parts up to 5 inches in diameter require the pre-stressed design to prevent die breakage.

The unstressed die holder shown in Figure 26 was made from SAE 52100 heat treated to R_c 48. The weld joint noted on the drawing was omitted in both holders and the guide pins were removed after original trials. The original intent was to bolt the holder to the bolster plate from below; however, constant bolt failures required a re-evaluation of the machine action. Analysis disclosed that to achieve a bolt mounting free from compression loading at any time the bolting must be from the top into the bolster plate. High speed movies were used to provide the desired information on the machine action. The change to top bolting eliminated bolt failure.

Typical of the forging die design for the unstressed holder is the F-106 fitting die MDA-146 shown in Figure 27. The tapered undercut area in both punch and die is used to retain the tool members in the tool holders by set screws. This taper provides an adequate lock for forging work. Keys are used in both punch and die to assure matching when mounting in the tool holders.

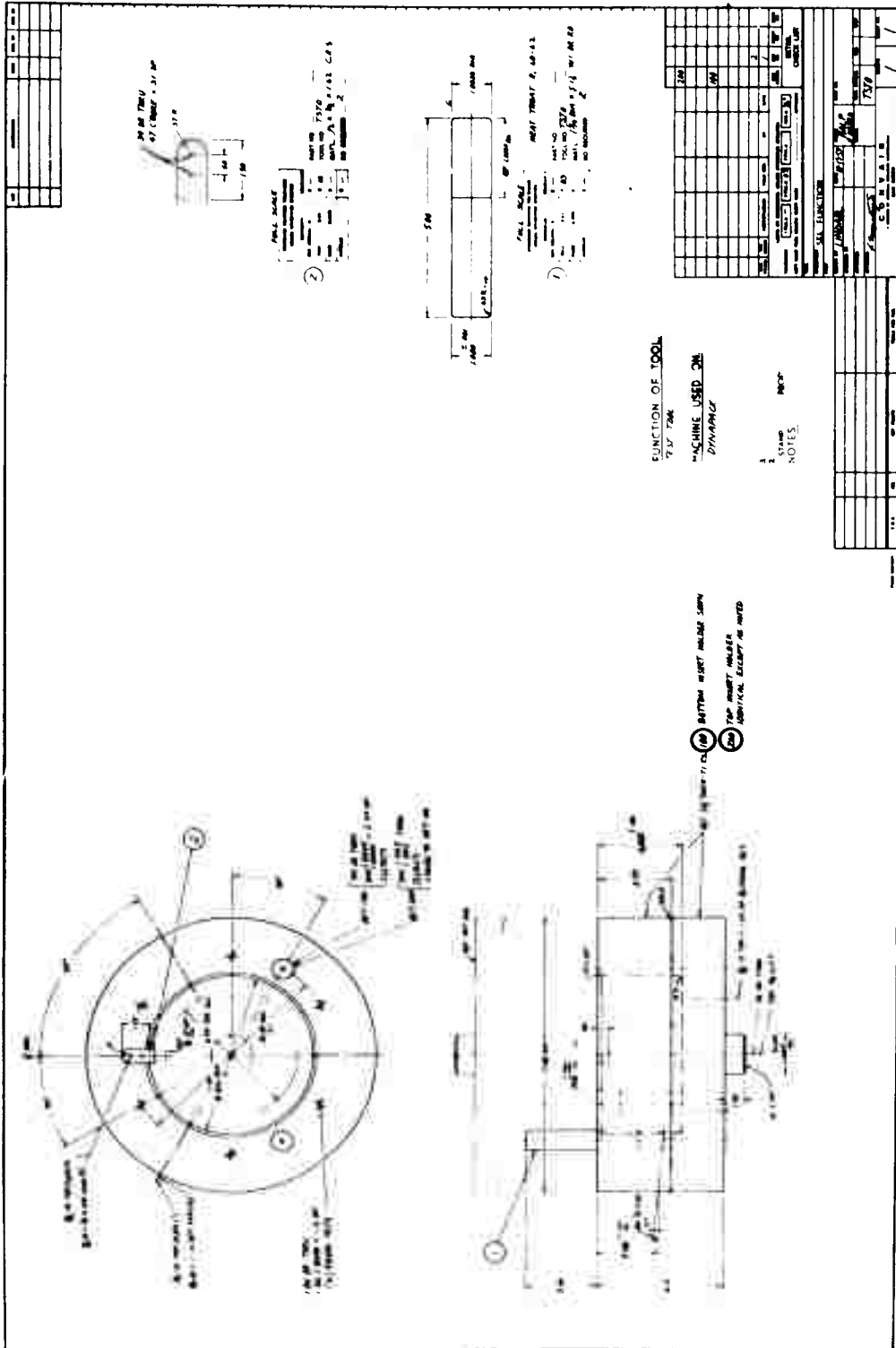


Figure 26 - UNSTRESSED UNIVERSAL DIE HOLDER.

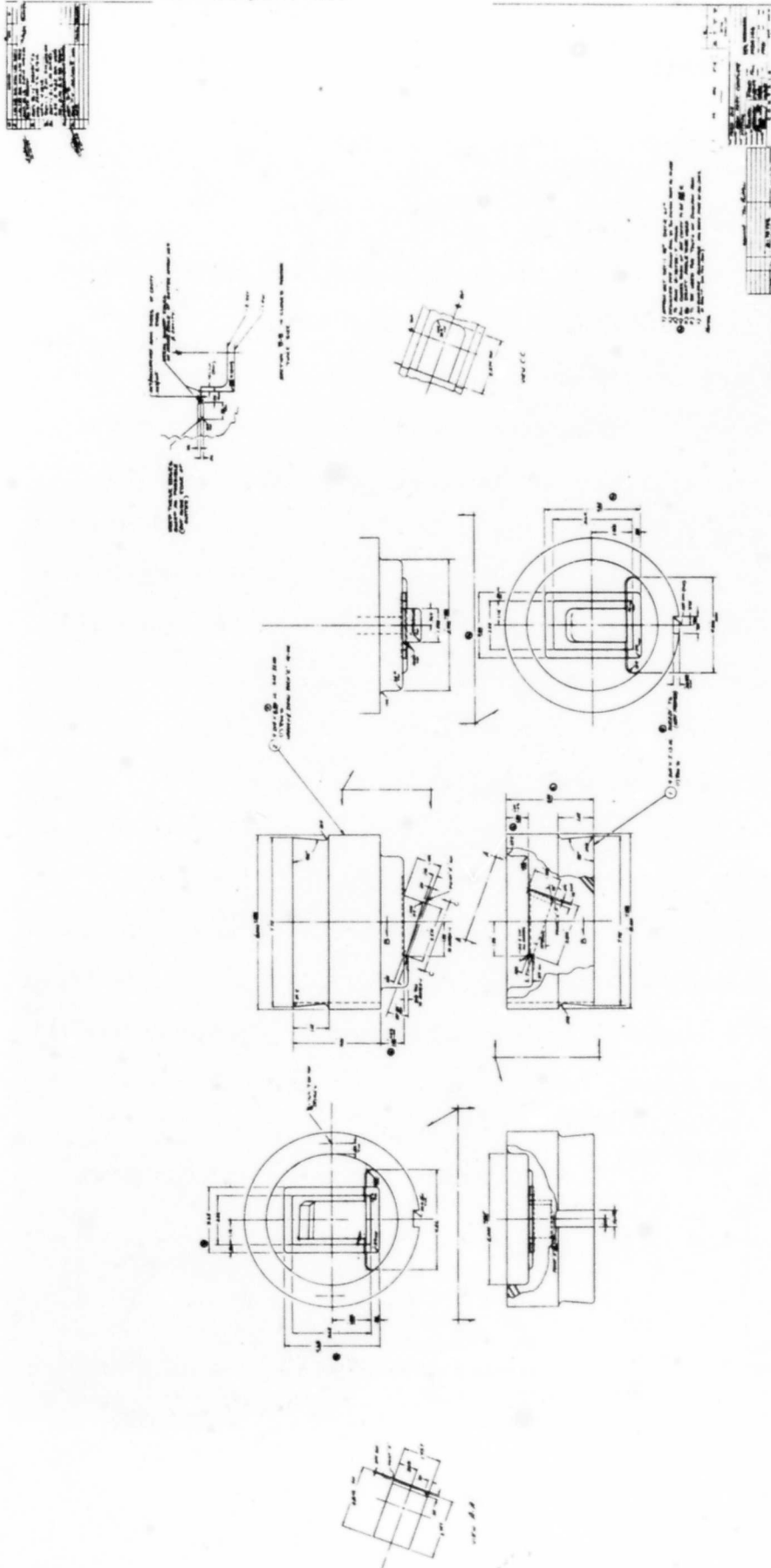


Figure 27 - TYPICAL FORCE DIE DESIGN FOR UNSTRESSED DIE HOLDER

GENERAL DYNAMICS/CONVAIR

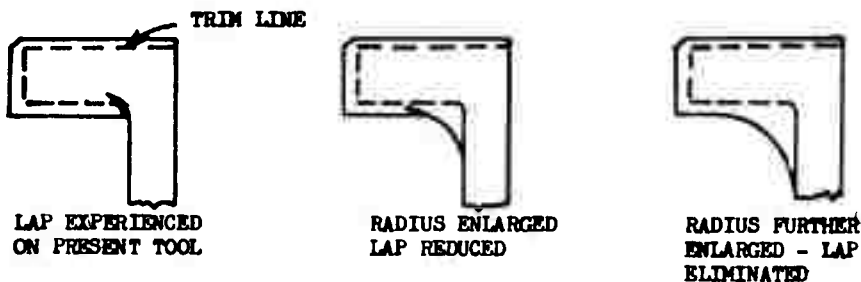
DEVELOPMENT OF THE PROJECT

(Forging - Tool Development)

Note the use of the lead-in on the die member to eliminate side thrust and provide a close tolerance matching of punch and die.

Control of material flow in forming is of great importance. Since the Dynapak technique involves speeds considerably beyond the normal forging rates, material flow must be closely controlled. The tool noted in Figure 27 allows a maximum of .010" in the trim area of the part. It was found during the tests that the area had to be reduced to trap the material and thus retard material flow in order to keep the part in one piece. The final proof out of tooling generally resolves itself into a cut-and try method to control flash and insure filling the die.

In closed die forging, where no flash provisions are made, flow control to prevent laps and voids is critical and may at times require design changes. An example of the type of problem is the bushing 8-16512 discussed earlier under part fabrication. The lap found in the upper flange area can be reduced or eliminated by a change in the flange radius. A larger radius in the area will improve the material flow and should a lap occur it will be in the part trim area (shown below).



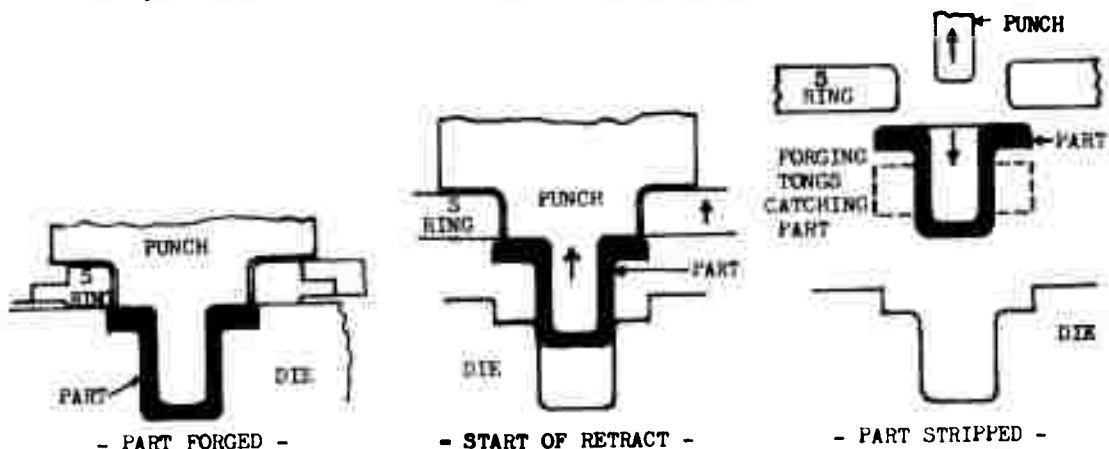
DEVELOPMENT OF THE PROJECT

(Forging - Tool Development)

A new forge die holder was made for the closed die forging trials. The holder provided for a stripper ring arrangement to strip the parts from the punch on the return stroke of the ram. The universal holder and stripper ring are shown in Figure 28. A view of the basic holder in Figure 29 shows the three additional stripper bolt holes, side slots and release knob modifications to the basic design.

Inserts were used in the stripper ring so that only one stripping ring would be required. Inserts were then made to fit the outer ring and the particular part for which they were intended. Since the actual stripper portion of the ring would become part of the die it was made of Durodi while the outer ring was made from SAE 52100.

Stripping action is provided by the return stroke of the press. As the ram returns the part, shrunk on the punch due to cooling, carries the stripper ring with it until the guide bolts stop the ring, stripping the part from the punch. A typical stripping sequence is shown below.



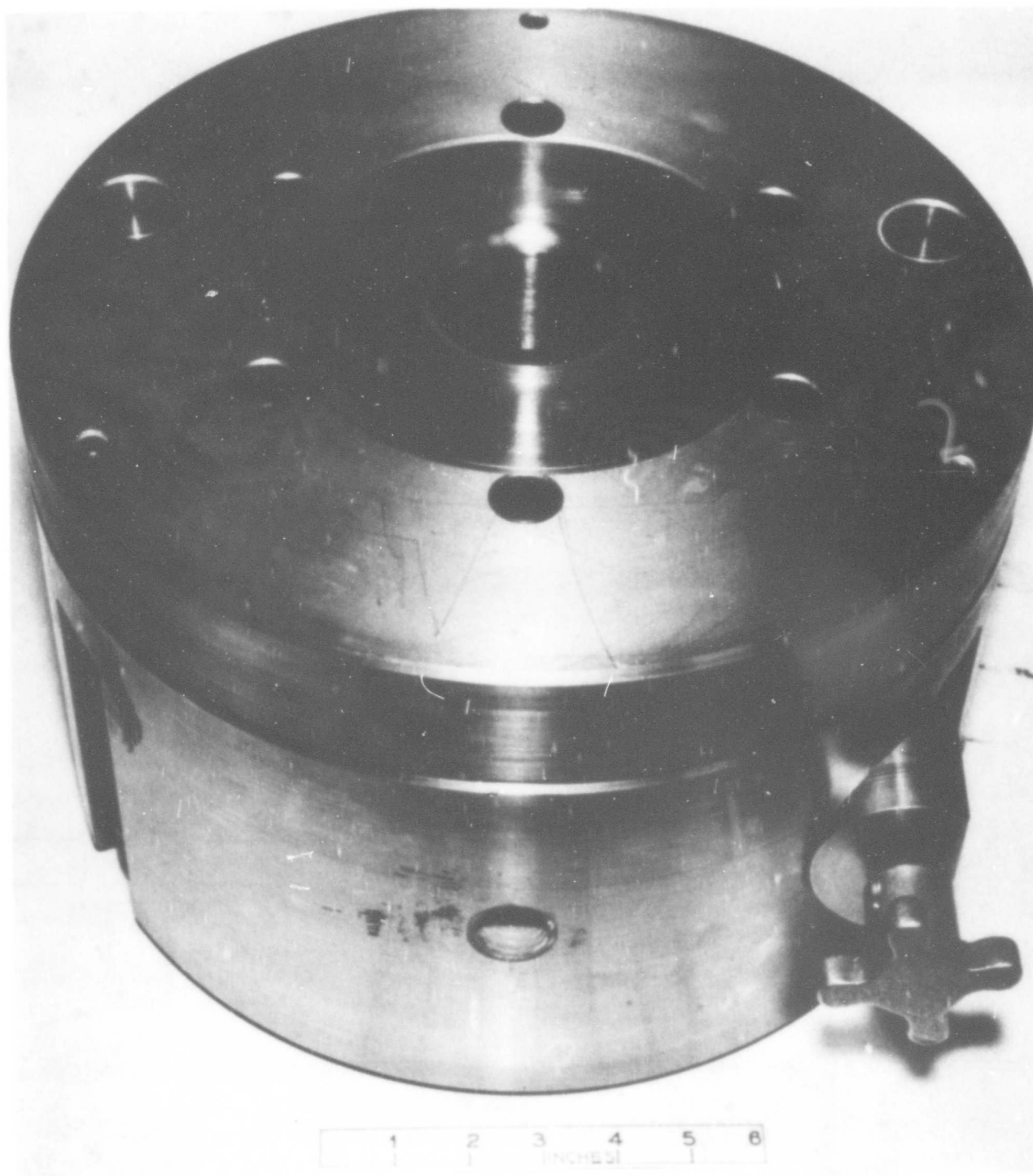


Figure 28 - UNIVERSAL HOLDER & STRIPPER RING

Convair Print 57028

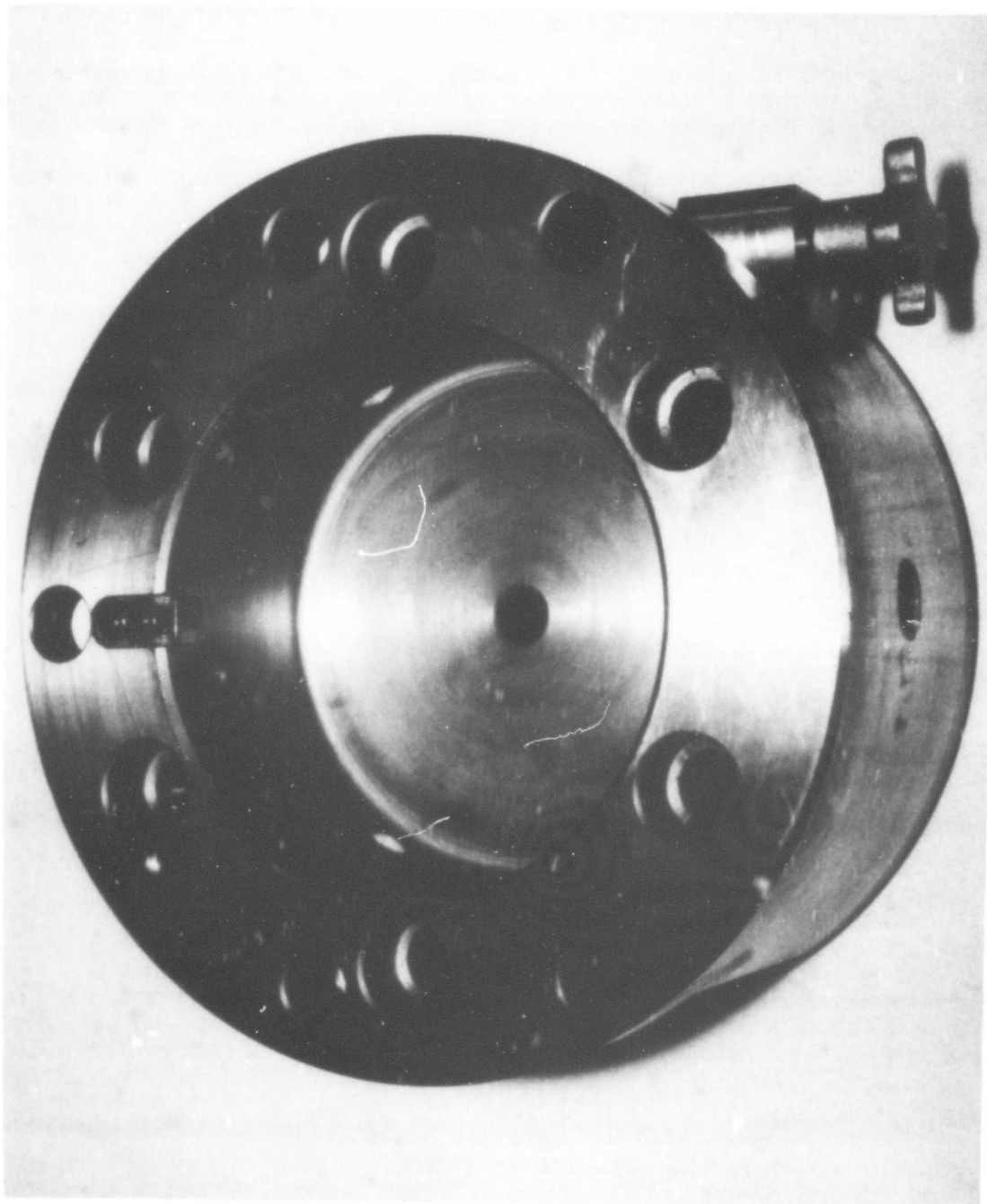


Figure 29 - BASIC HOLDER LESS STRIPPER RING

Convair Print 57027

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

(Forging - Tool Development)

The stripper ring will remain in the extended position until the release knob is pulled, allowing the ring to drop into position on the holder. In most cases the ring was left in the up position shown in Figure 30 until the next billet had been placed in the die cavity. The ring was then released and the machine fired.

Since the holder and outer stripper ring were standardised it was necessary only to make a punch, die and stripper for a detail part. Typical of the tooling required are the components for the bushing. P/N 22-51001-21 shown in Figure 31.

(Foreward Extrusions-General Notes)

The Dynapak extrusion button varies from the convention. button in that it appears that no lead-in is required to achieve the desired extrusions. A ring of metal is left in the scalp of the extrusion billet and often is separated from the scalp due to material flow during the extrusion stroke.

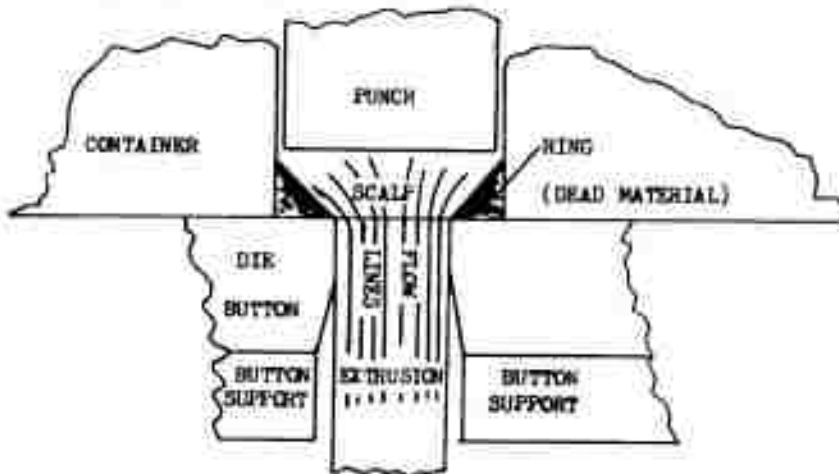
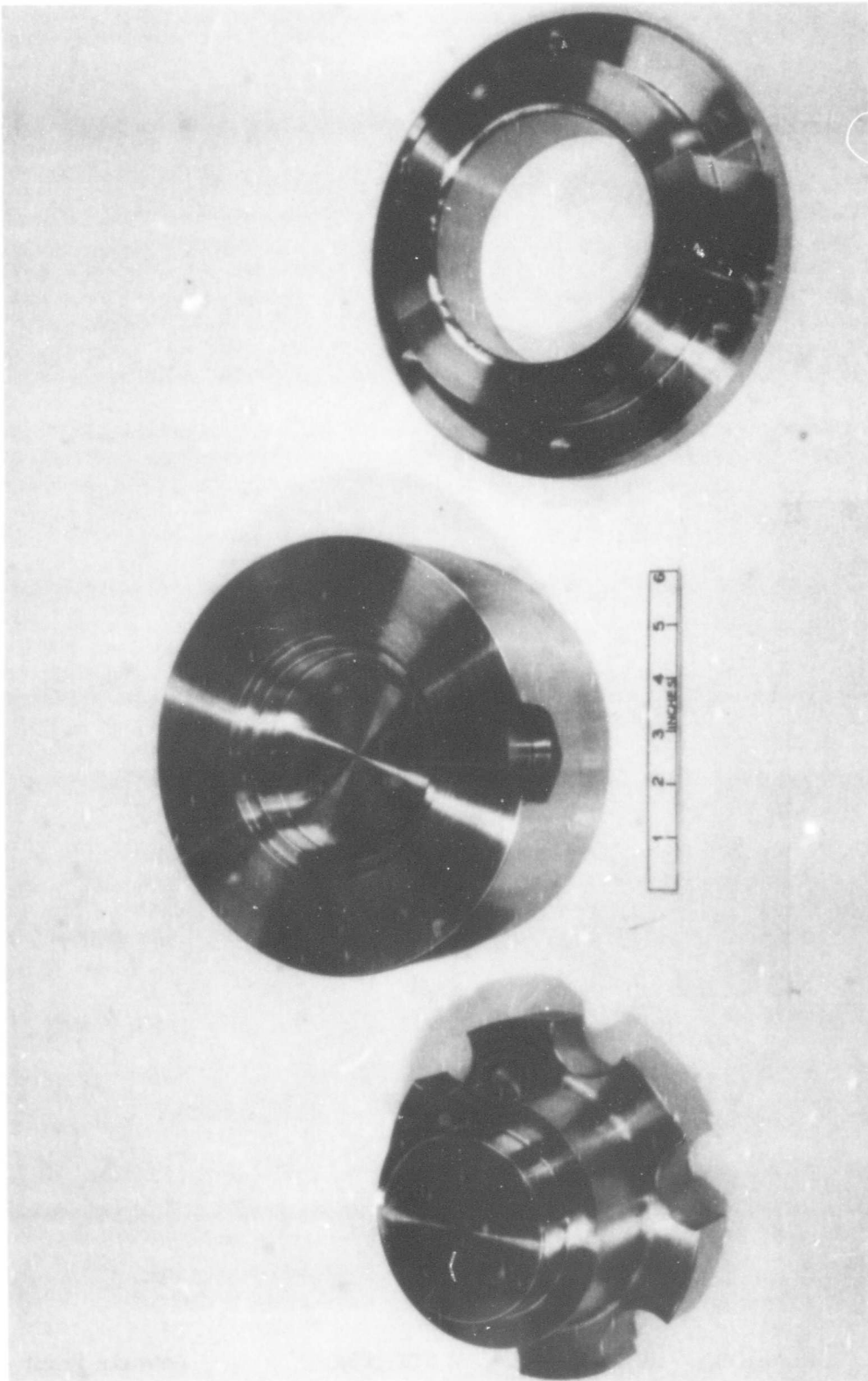




Figure 30 - BASIC HOLDER WITH STRIPPER
RING IN UP POSITION

Convair Print No. 57029



Convair Print 57335

Figure 31 - TYPICAL BUSHING TOOLING

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

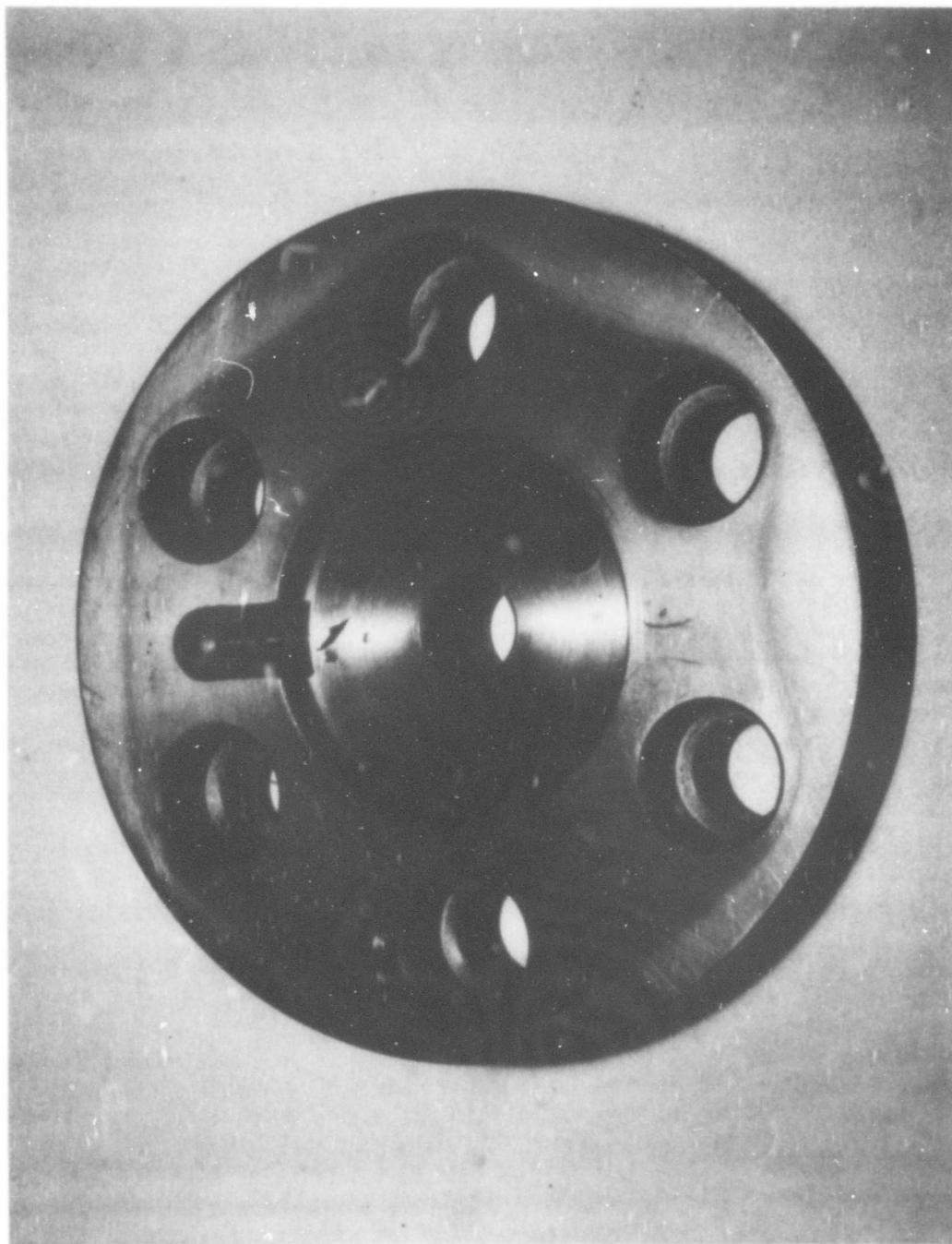
(Foreward Extrusions-General Notes)

Attempts to duplicate the dead material ring in the container design have not been fruitful and it is felt that the limited improvement, if any at all, would not warrant the increased complexity of extrusion button design and manufacture.

(Tool Development)

Punch holders were developed in the same manner as the die holders, by test. The first punch holder, MDA 500 shown in Figure 32, was made from SAE 52100 tool steel heat treated to R_C 48. This holder failed when used in a forging attempt and is seen in Figure 33 after removal from the machine. As a result of this failure a new holder, incorporating sub plates hardened to resist the high compression loads, was made. The first plate was heat treated to R_C 58-62 which proved to be too hard and brittle. A subsequent plate was tooled from Durodi steel, heat treated to R_C 45-46. This choice was made as a result of the excellent showing of Durodi in the forging tools. The new sub plate has been used in forging, extruding and compacting tests and still is in good working condition. The new universal punch holder MDA 501 is seen in Figure 34.

In addition to the punch holder development a pre-stressed extrusion tool holder was developed. The design seen in Figure 35 is unique in that both the billet container and the die button are independantly pre-stressed in the same tool. The design also allows the billet container to be removed without bothering the die button. In addition the die button is backed up heavily to prevent failure.



Convair Print 57001

Figure 32 - FIRST PUNCH HOLDER BUILT

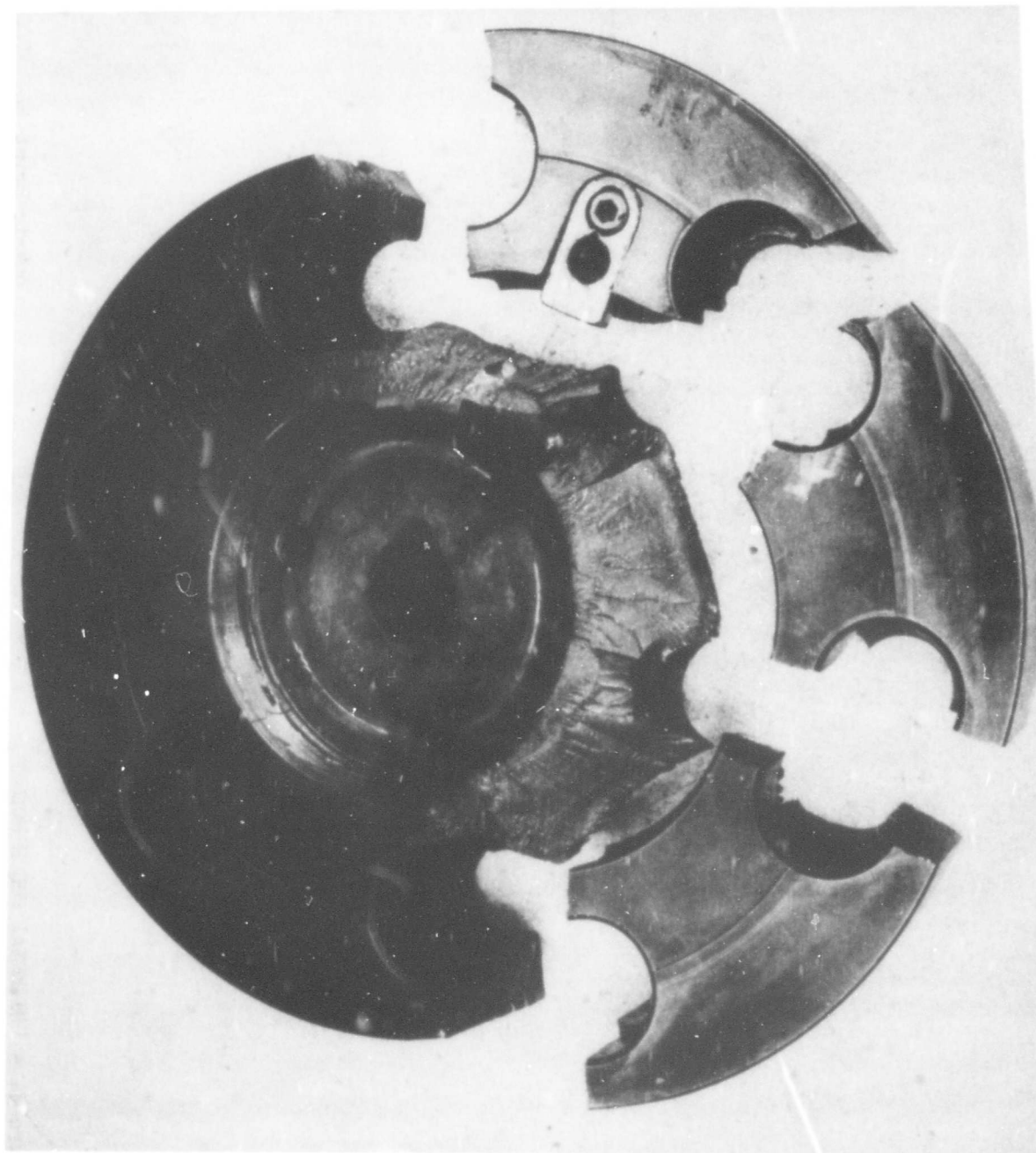
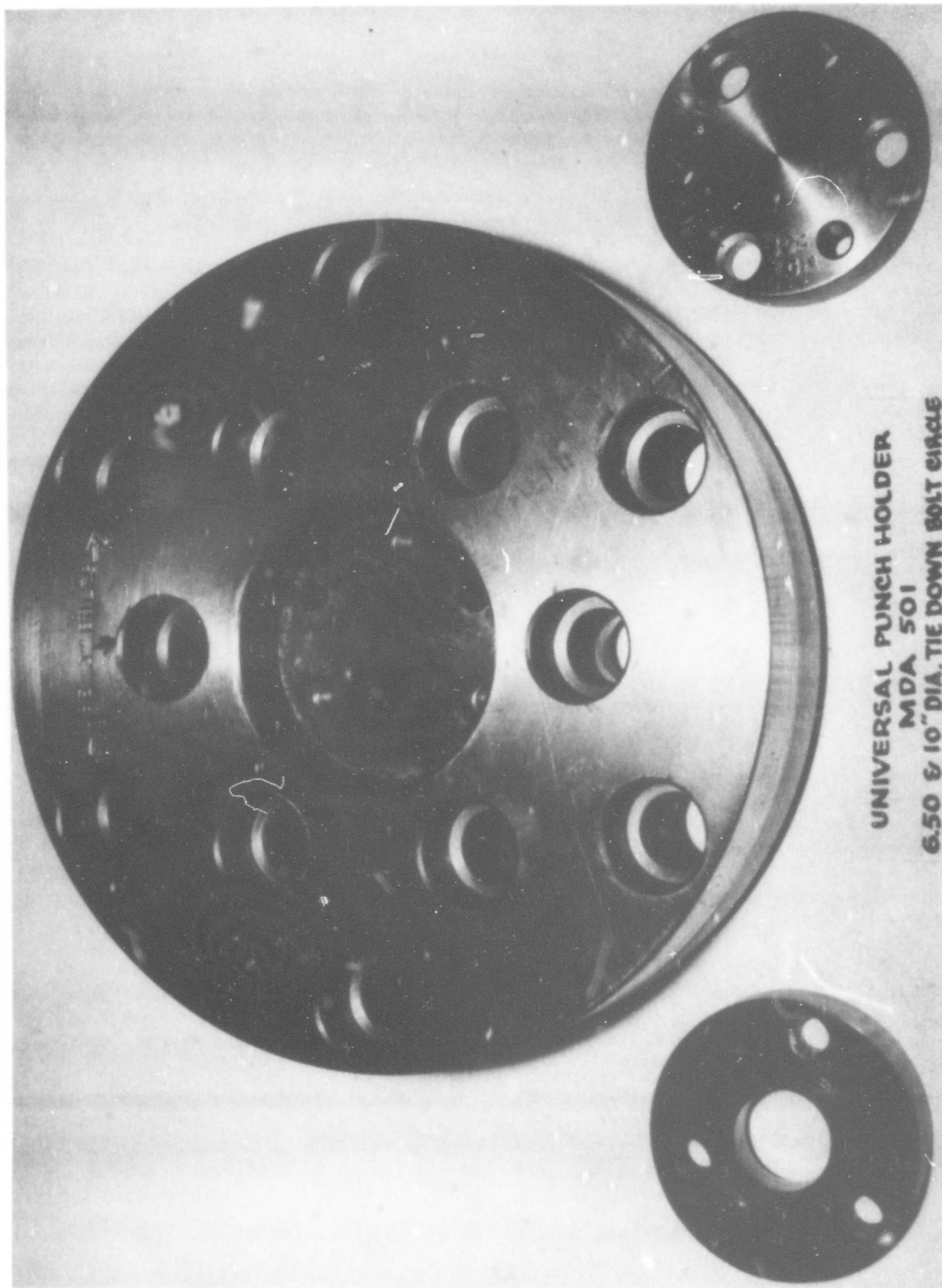


Figure 33 - PUNCH HOLDER FAILURE

Convair Print 58862



Convair Print No. 57002

Figure 34 - UNIVERSAL PUNCH HOLDER

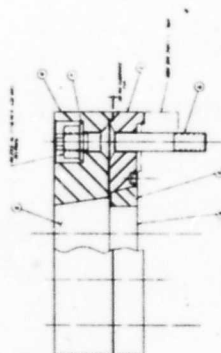
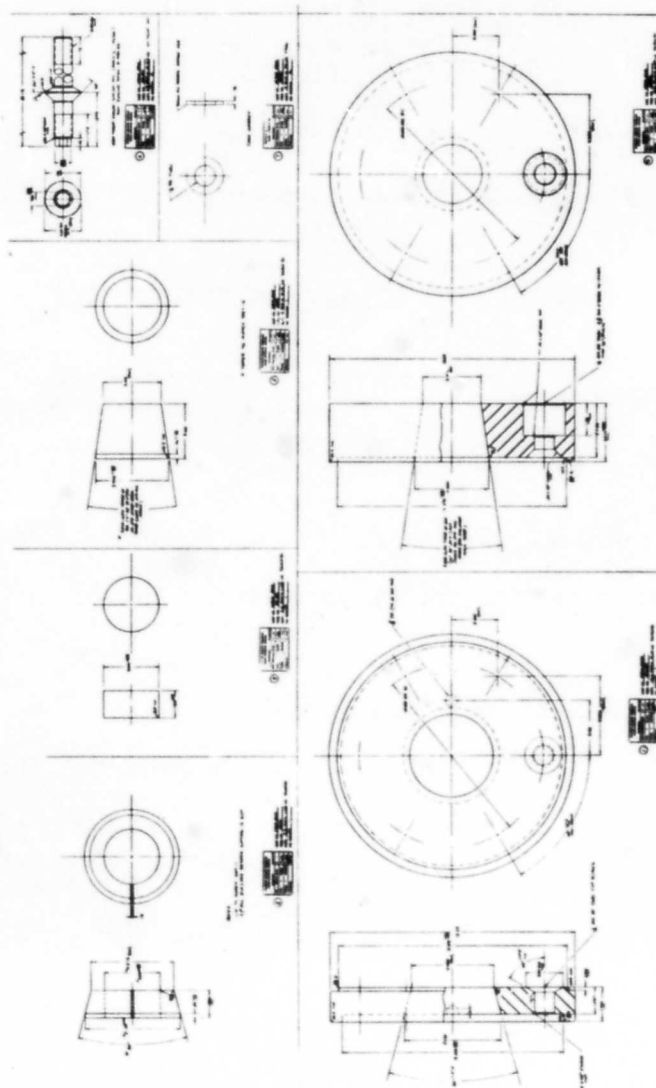


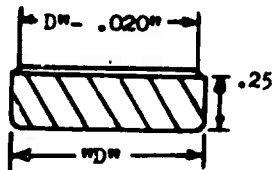
Figure 35 - PRESTRESSED EXTRUSION TOOL HOLDER

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

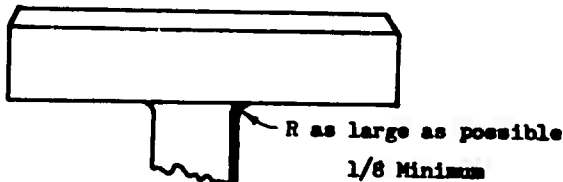
(Tool Development)

Punch design is more or less determined by the part. There are however some basic design features common to all punches. On all straight punches it is best to relieve the punch about .020 on the diameter starting from approximately 1/4 inch behind the contact face. The contact face may be



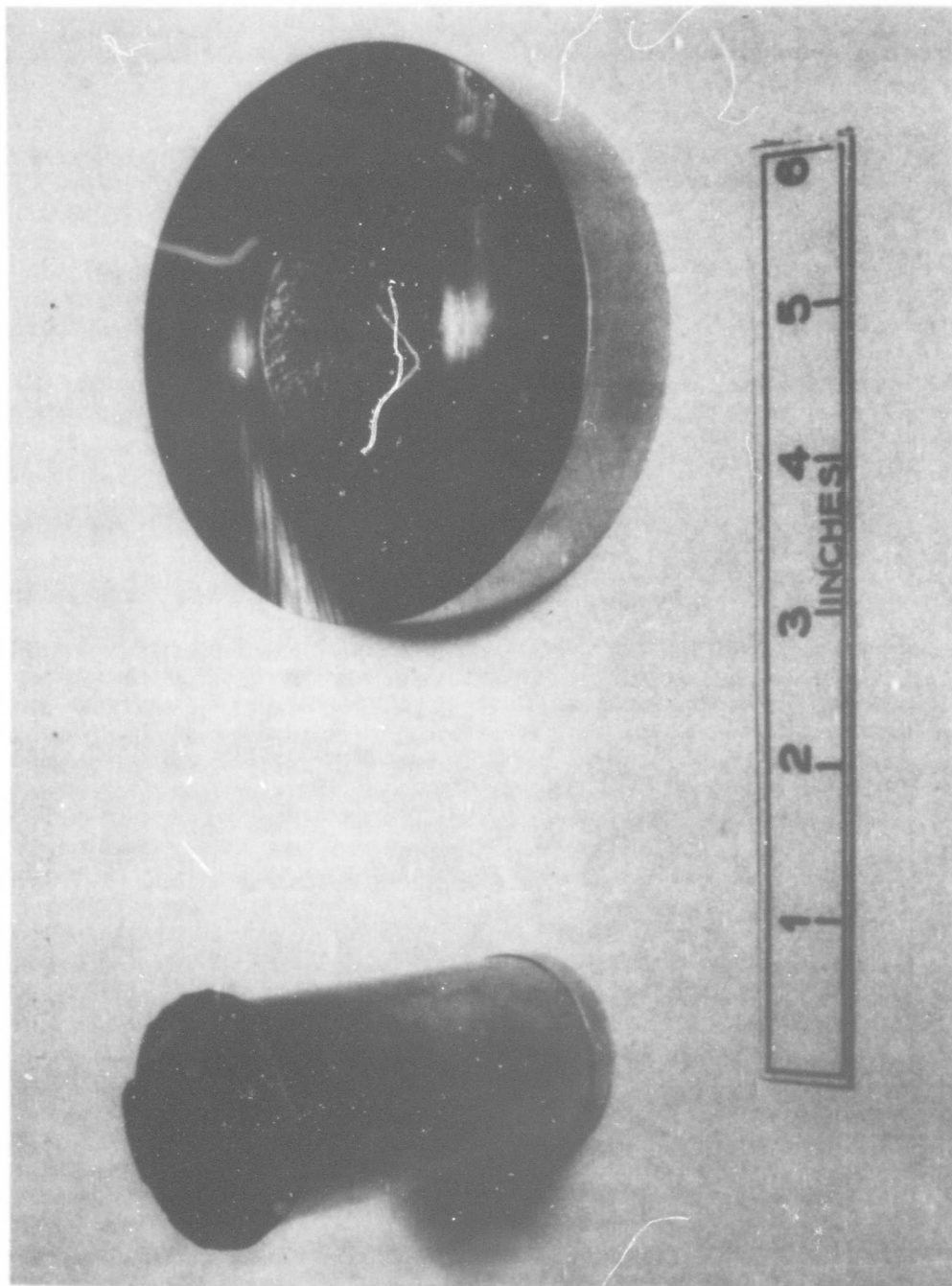
separate so that replacement may be made without scrapping the whole punch.

If at all possible a large radius should be used between the shank & butt.



In most cases radii of between 1/8 and 1/4 are satisfactory however, the smaller the punch diameter the greater the need of a large radius for strength.

Test evaluations established that punches hardened in excess of $R_c 50$ were too fragile for normal use. Machine side play and slight billet unevenness resulted in broken punches. Typical of the failures experienced in the punch shown in Figure 36. However as the punch hardness was reduced a tendency to mushroom on impact was noted. Figure 37 illustrates



Convair Print 54924

Figure 36 - TYPICAL FAILURE OF HIGH HARDNESS PUNCH

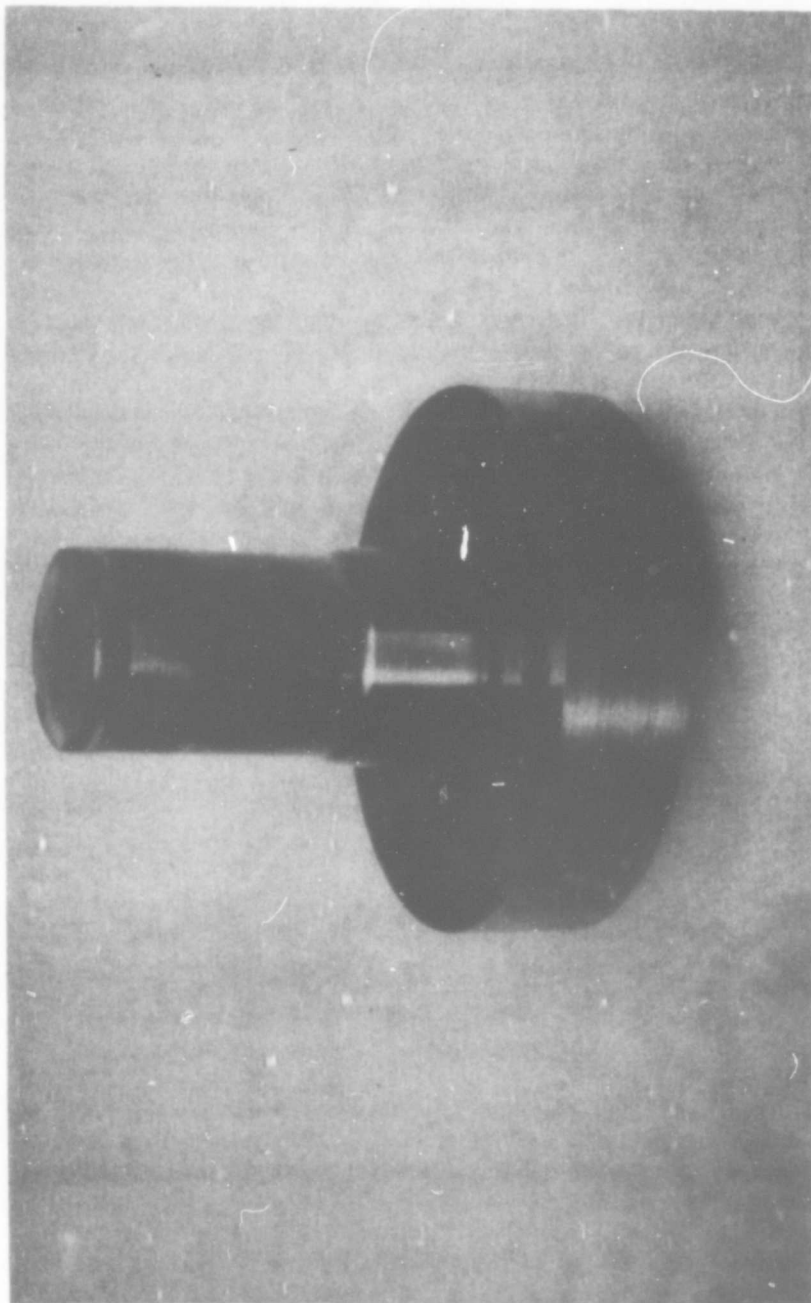


Figure 37 - TYPICAL UPSET FAILURE OF PUNCH

Convair Print No. 54865

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

(Tool Development)

a typical punch upset from excess compression loading. It is believed that the best hardness range for punches is between R_c 46-48. There will still be a tendency to upset the punch when excessive fire pressures are used. No set figure can be given for punch size to fire pressure relationships since it will vary from material to material, by forging temperature, by reduction ratio etc. however information in this area for extrusion application is being developed by the Dynapak project personnel.

Extrusion button design is quite simple when no lead-in is provided. The desired cross section is cut into the round button and is relieved below the first $1/4$ inch. Reference Figure 38. A view of the button is shown in Figure 39. Although the die button thickness of $1-1/2$ inches seems sufficient, tests established that a heavier back up around the desired cross section is mandatory to prevent button failure.

Backward Extrusion

Only a limited amount of work was done with back extrusion; however, the tooling developed in the forward extrusion testing was found to be satisfactory for general usage. The punch was rounded rather than flat to achieve a better flow of material and reduce the punch loading upon impact. Flat bottom punches should be avoided since they retard the flow of metal directly below the punch face. For optimum metal flow and reduced punch loading the punch should have a cone angle of from one to seven degrees with a minimum radius blend in to the punch land of .032." (Figure 40)

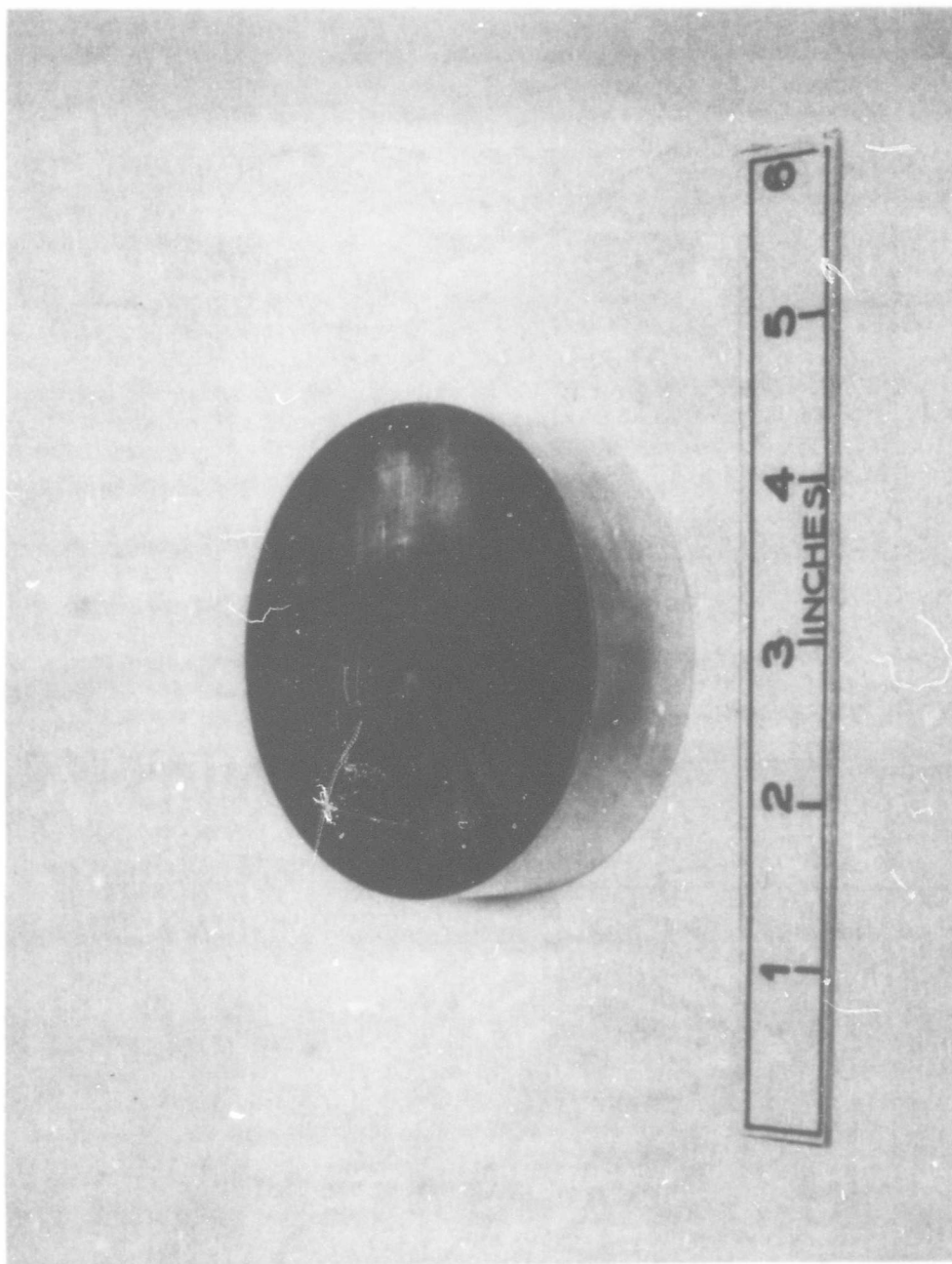


Figure 39 - EXTRUSION DIE BUTTON

Convair Print 54923

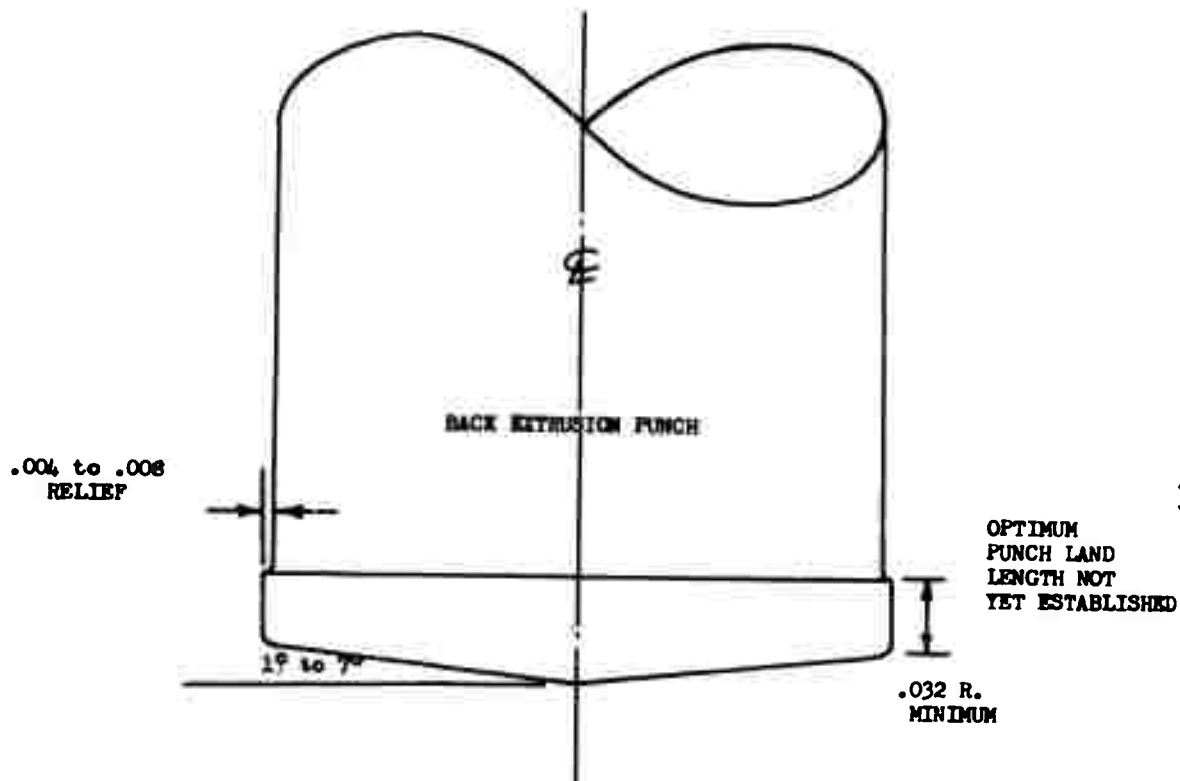


Figure 4.0 - OPTIMUM BACK EXTRUSION PUNCH DESIGN

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Backward Extrusion

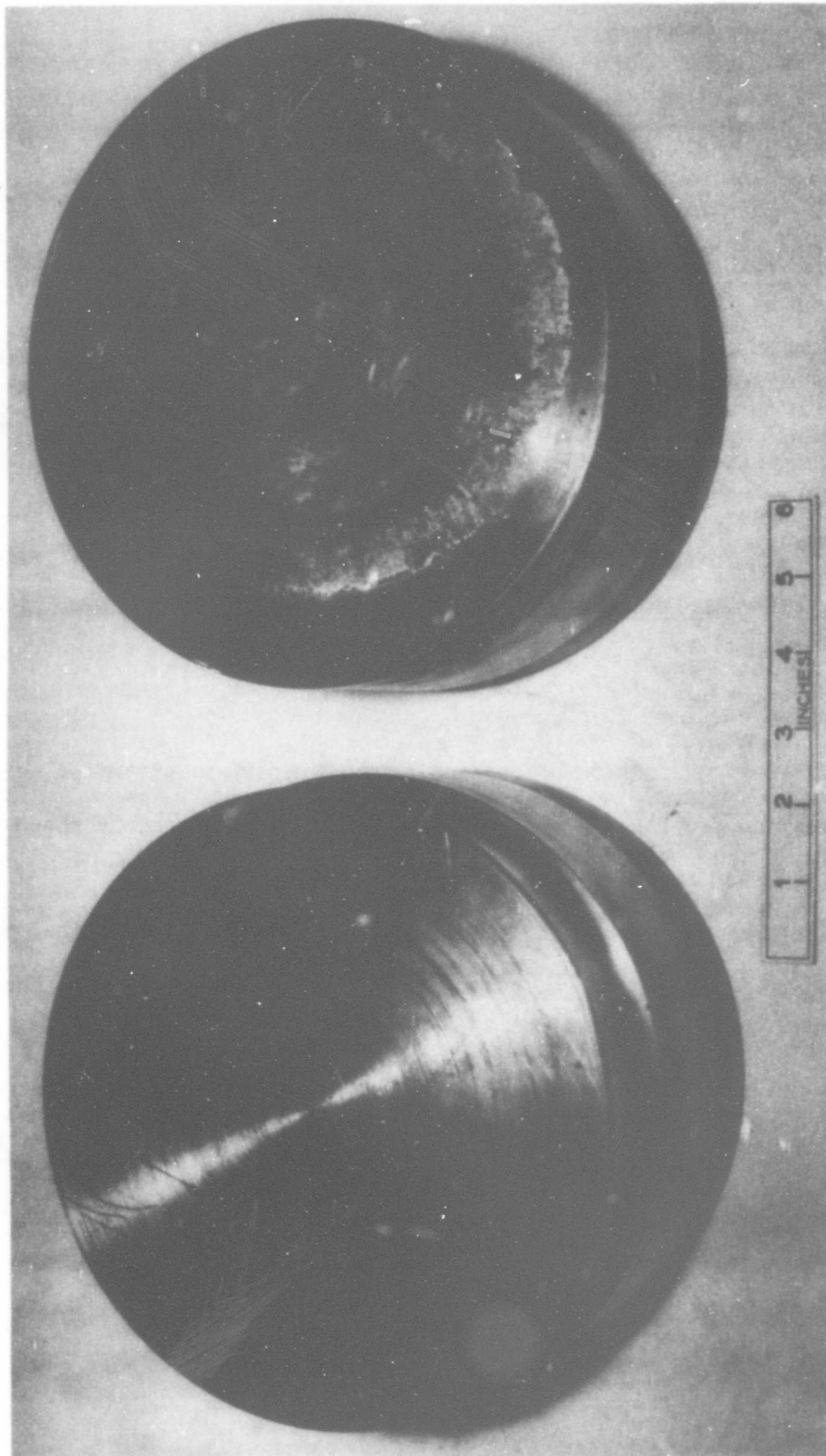
It was found that a .004" to .008" relief in contrast to the .020" used on the forward extrusion was necessary to control size. Secondly the length of the non-relieved section was found to be important. A short length of the land is best, since side friction is reduced. If the land is too short, size tolerances are lost. There was insufficient work done in this area to establish a minimum land size. It is believed that the land size will depend to a great extent on punch size and material to be extruded.

As with all tooling which is used in the forging and extruding areas, surface finish is extremely important. A mirror finish on the punches and dies is a definite asset.

Compacting

A preliminary evaluation of compacting by Dynapak was attempted using tungsten carbide pre-pressed powders. A flatter die assembly shown in Figure 41 was used in the trials.

A rectangular shape was cut in a piece of hot rolled steel. The opening was filled and the powder pre-pressed prior to the forging stroke. The steel and powder pre-pressed prior to the forging stroke. The steel and powder were then hit and reduced in thickness. Powder density was increased but the stresses set up by the forged steel holder cracked the compact before the piece could be sintered.



Convair Print No. 57004

Figure 41 - FLATTENING DIES FOR COMPACTION ATTEMPT

GENERAL DYNAMICS/CONVAIR

DEVELOPMENT OF THE PROJECT

Compacting

Although the results were somewhat disappointing, the tests did lay the groundwork for Project 348, a compaction study.

Materials

It was found that Durodi, a shock resistant tool steel, was an excellent all around material. The SAE 52,100 material was found to be satisfactory for holders and holder rings but was not sufficiently shock resistant for the forging die or punch section. Punches made of Graphite tool steel were tried but proved susceptible to brittle failure due to side loads.

It was found that high hardness was not necessary to satisfactory punch performance. In general it may be said that hardnesses exceeding $R_c 50$ should not be used in the tools subject to impact and shock loads. Tool steels selected for Dynapak use should be capable of withstanding high thermal shock and impact loads and yet retain the strength level required. The Durodi material does fairly well but many improvements can be made. As yet there are no tool steels manufactured that meet the drastic requirements of the Dynapak operation.

GENERAL DYNAMICS/CONVAIR

A P P E N D I X

MACHINE OPERATING INSTRUCTIONS

General Operating Instructions

Safety Precautions

The Dynapak machine is a safe machine when handled with respect. It's ability to release tremendous forces in milliseconds requires that each action be thought out prior to initiation. A careless operator will find it an extremely dangerous machine unless he follows the simple and logical rules which follow:

NEVER put the hands under the ram unless it is held up by hydraulic oil pressure. Without the oil under the ram piston, even the "safe" position of the control switch is unsafe.

WATCH the fire pressure and set pressure gauges and be sure that the ratios are maintained 3 to 1. NOTE: Fire pressure may gradually build up from trigger gas or set pressure leakage could make the machine misfire.

REMEMBER the PANIC BUTTON is the fire pressure bleed valve on the console. Opening this valve dumps the fire pressure to the atmosphere and the machine cannot fire.

When energizing the machine, ALWAYS put the fire pressure in last.

When de-energizing the machine, ALWAYS dump the fire pressure first.

When the machine is left unattended it should be in the safe position with oil under the piston. All electric power and the nitrogen gas supply to the console should be cut off.

In the event of a electrical power failure if the rotary switch is in the fire return, or cock position, the machine will dump the fire pressure to the atmosphere thus, making it safe automatically. If the machine is in the safe or ready position, it cannot be fired electrically, but it does remain energized and will misfire if the 3 to 1 fire pressure to set pressure reaches 4 to 1.

MACHINE OPERATING INSTRUCTIONS

General Operating Instructions

Safety Precautions

All bolts, nuts and other structural parts of this machine are made of heat treated alloy steels. (DO NOT SUBSTITUTE).

Never attempt to disassemble the machine unless all gas is dumped, all bleed valves excepting back pressure bleed valve are open and the high pressure gas supply is shut off.

When firing, stay out of splatter area or use the safety door.

Test Firing

The (6) end caps on each end of the (3) shock absorbers should be turned counterclockwise with a spanner wrench to be sure they are tight against the (6) bearing feet.

Insert the six inch spacer adjustment bolt between the top of the lower cover plate and the bottom of the right front bearing foot.

Turn on the utilities as follows:

110 Volt AC to the console

Nitrogen manifold gas supply to the console

440 Volt 3 phase current to the pump unit

Open the pressure "X" valve above the left gauge on the left side of the machine. It will take about 750 psi to raise the machine to obtain the 6" dimension from the frame.

Close pressure "X" valve and open pressure "Y" valve above right hand gauge on left side of machine. Admit 250 psi to the upper shocks.

Close pressure "Y" valve and remove 6" bolt for established (6") neutral position before firing.

GENERAL DYNAMICS/CONVAIR

MACHINE OPERATING INSTRUCTIONS

Test Firing

The machine is now ready for test firing, and it can be shot against a high back pressure so that the column will move only a few inches.

Close the set pressure bleed valve on the console and open the set pressure to build a pressure of 35 psi in the MYGE unit.

Check the back pressure bleed valve (It should never be opened or hydraulic oil will be exhausted onto the floor under the console.) Turn the back pressure fill valve to the right and build up a gas pressure under the piston of 100 psi. This is a diaphragm valve. It opens to the right and is left open to maintain the pressure selected, automatically.

Close the fire pressure bleed valve, and very slowly open the fire pressure fill valve and reach a pressure of 100 psi.

IMPORTANT: Never exceed a three to one pressure ratio between fire and set pressures or the machine ~~may~~ misfire automatically. From this time on until firing the machine is energized, so do not approach it bodily. Use tongs to place or move parts in the work area.

Start the pump with the manual switch to the right of the oil pressure gauge at the left end of the console.

Set the rotary switch to the "Ready" position (pointing straight up)

Turn the 110 volt toggle switch to "on" and the machine is ready.

As the rotary switch is turned counterclockwise the following events take place:

Fire - The machine should fire and the column moves out very rapidly, but for a short distance, because the back pressure is high enough to stop it.

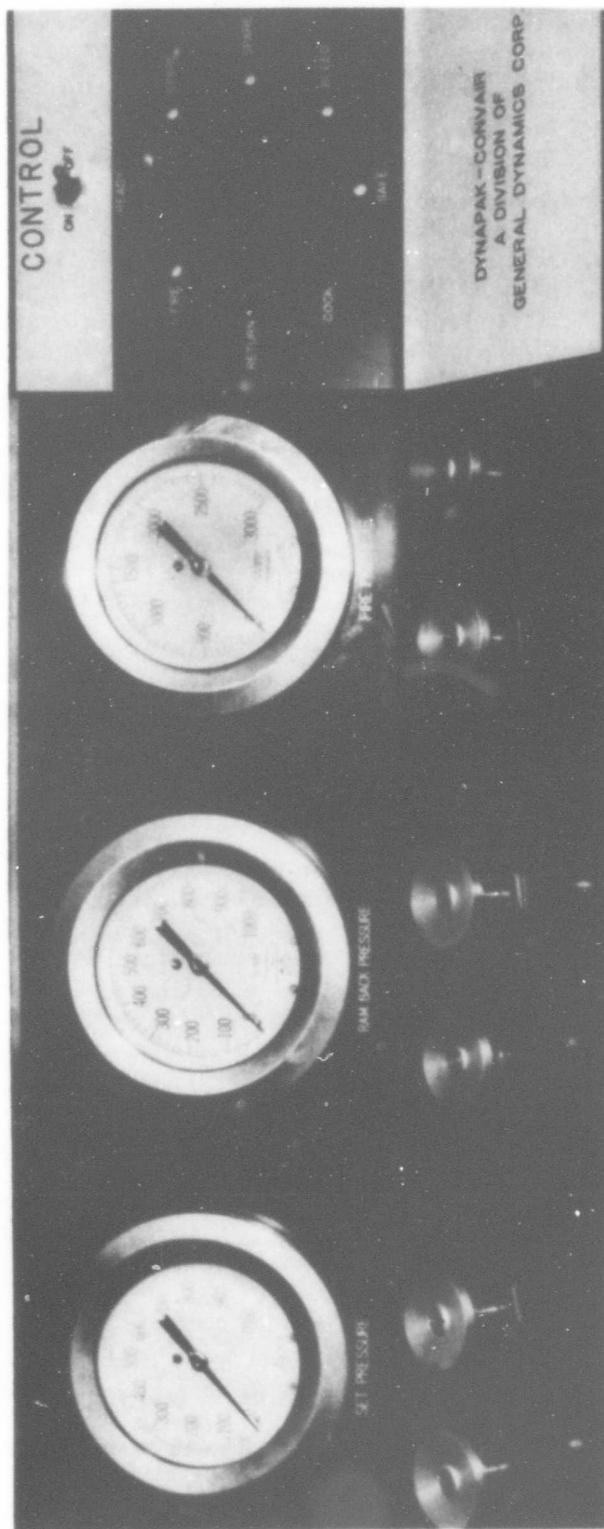


Figure 42 - Operating Console Controls

MACHINE OPERATING INSTRUCTIONS

Test Firing

Return - This position energizes a solenoid valve which then allows hydraulic oil to be pumped under the ram piston and returns it to the starting position. When the green light comes on and the hydraulic oil pressure gauge reads approximately 2300 psi the piston is up against the seal plate and the operator may move the rotary switch to the next counter-clockwise position.

NOTE: On the first run, the pump must purge itself, and this may take some time.

The "cock" position pumps oil into the set pressure system of the Hyge unit and returns the seal base to its starting position. Allow a minimum of five seconds in this position. When the green light comes on, the operator may move the rotary switch counter clockwise to the "safe" position.

Safe - At this point the machine has been re-cocked, but the hydraulic oil is still under the piston, hence the piston could move but a very short distance even if accidentally fired. This is the safe position for changing tools, etc. This is also the position to leave the machine in when it is not to be operated for a short time. If there is no need to have the machine in "safe" position (as with rapid firing) this position is passed through without stopping at all.

Bleed - With the rotary switch in the bleed position the hydraulic oil is returned to the reservoir and the machine is again ready to fire. The operator must hold this position until the red light comes on indicating the bleed is complete.

GENERAL DYNAMICS/CONVAIR

MACHINE OPERATING INSTRUCTIONS

Test Firing

Spares - Two spare positions are included in the cycle to be used as desired. These positions can be used for such purposes as regulating purge gas, tripping an automatic billet feeder, or blasting a forging die with gas to remove scale.

NOTE: If the machine is in the "ready" position and it is desired to return to the "safe" position without firing, turn the rotary switch CLOCKWISE to the return position. The pump will then fill the piston back pressure chamber "B" full of oil. The normal, counterclockwise, rotary switch sequence through to the "safe" position should then be followed.

IMPORTANT: The set pressure and the ram back pressure gauge readings are erroneous for gas pressure indication when there is oil in the machine. For this reason a spare or ready position of the rotary switch is necessary for setting pressures desired. Always work from left to right adjusting the set pressure to 1/2 the desired fire pressure; then adjust the diaphragm fill valve to maintain 100 psi ram back pressure. (This pressure is used for all fire pressures above 300 psi.) Next adjust the fire pressure to twice the set pressure. Lastly, open the set pressure bleed valve on the console slowly and drop it to 1/3 the fire pressure. If this ratio is exceeded the machine will automatically misfire without movement of the rotary switch. Set pressure gas fills a small area in the hyge unit and very little is wasted for the additional safety obtained as outlined above.

MACHINE OPERATING INSTRUCTIONS

Test Firing

CAUTION: NEVER allow anyone near the machine when gauge pressures are being set or adjusted.

Machine Malfunctions :

Going back through the preparations for firing, and the test firing the following list covers most malfunctions and their probable causes.

One of the fill valves on the console is opened to raise a pressure in the machine and nothing happens.

(Probable Cause)

The valve on the nitrogen gas bottle was not opened.

Remedy: Open the valve on the gas bottle.

Nitrogen pressure in the bottle is too low.

Remedy: Close the valve on the bottle and open a valve on a bottle containing more pressure.

Should the bottle pressure be less than the machine pressure, the machine will bleed into the bottle until the pressures are equalized. This principle can be utilized to conserve gas in many cases. For example, rather than exhaust fire pressure to the atmosphere the excess gas may be bled into a near empty bottle thus saving the gas for future use.

MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

The fire pressure valve is opened to introduce fire pressure and the gas exhausts to the atmosphere:

(Probable Cause)

The Hyge unit is not seated.

Remedy: Increase set pressure gauge reading to possibly 800 psi.

If there is dirt on the actual seal, actuation of the machine may blow it out. If permanent damage to the seal has been done the machine must be disassembled to correct the condition.

The rotary switch is moved to the fire position and nothing happens:

(Probable Cause)

110 volt toggle switch on the console in off position

110 volt power to the console off: at the fuse box

Fuse block on the 110 volt system has blown

The nitrogen gas supply was not turned on at the bottle.

The trigger gas solenoid valve mal-functioned.

Remedy:

There may be a short in a wire from the console to the solenoid mounted on the left side of the machine.

MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

After firing, the rotary switch is moved to the return position and nothing happens.

(Probable Cause)

440 Volt 3 phase power to the pump unit was not turned on

The 110 volt AC power from the machine console to the hydraulic pump solenoid valve is disconnected.

The 440 volt circuit breaker at the hydraulic pump has opened.

Remedy:

Turn on the power.

The hydraulic pump returned the ram piston to the seal plate but the green light did not come on to indicate a completed cycle.

(Probable Causes)

Signal light bulb burned out.

Improper adjustment on pressure switch in the signal light circuit.

The rotary switch is moved to the "SAFE" position and the fire pressure starts exhausting to the atmosphere.

(Probable Cause)

Hyge unit not seated.

Remedy:

Quickly return the rotary switch to the fire position. This closes a solenoid valve and prevents further exhaust and loss of fire pressure gas. Move on to "Cock" position and start the hydraulic pump and hold at full pressure for ten seconds. Return to "Safe".

MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

Having passed the "Bleed" position on the rotary switch the machine is ready for use. After repeated cycling it is observed that the fire pressure is changing. If this condition is not rapid, it would be advisable to correct for it periodically by adding or bleeding gas as required to restore the desired value. If on the other hand rapid changes occur the time delay relay inside the right front end of the console should be adjusted. This relay is timed to put in as much gas on firing the machine as is lost on recocking it. When the timing is correct, the fire pressure will remain nearly constant. Increasing the delay will put in more gas (increase fire pressure) and decreasing the delay will put in less gas. Because the bottled gas supply pressure is not constant some variation in fire pressure is unavoidable.

Tool Installation

Punch and die alignment can be checked by advancing the ram toward the bolster at low velocity and under positive control. To do this the following procedure is required:

Energize the set pressure to a moderately high value. If the machine is empty of all gas pressure charge the set pressure to 400 to 500 psi.

Adjust the ram back pressure to 100 psi.

Adjust the fire pressure to 100 psi.

Bleed the set pressure back to 35 psi.

Fire the machine by advancing the rotary switch to the fire position. Because of the balanced back pressure and fire pressure the ram will advance a short distance and stop. NOTE: Leave the control switch at the fire position.

MACHINE OPERATING INSTRUCTIONS

Tool Installation

Bleed off all set pressure to guarantee that the set pressure unit will not close during subsequent maneuvering.

Advance the ram into the tooling by adding fire pressure manually.

Retract as required by bleeding fire pressure manually.

When tool check out is complete, adjust the set pressure to a value of 400 psi or more, advance the control switch to return and complete the operating cycle to the ready position. The machine may then be recharged to the operating conditions.

GENERAL DYNAMICS/CONVAIR

ACKNOWLEDGMENTS

GENERAL DYNAMICS/CONVAIR

ACKNOWLEDGMENTS

Operating Instructions for the 1200 Dynapak were obtained from General Dynamics/Advanced Products Department. The instructions given in this report were modified for the Convair updated machine.

Credit is due to Mr. J. T. McCormick and Mr. T. J. Critton (General Dynamics/Advanced Products Department) for their ideas and efforts which contributed greatly to the success of this project.